

AQA A-LEVEL PHYSICS

PHYSICS



EXAM QUESTION PACK

UNIT 5D TURNING POINTS OLD SPECIFICATION PAPERS

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Centre number

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Candidate number

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Surname

Forename(s)

Candidate signature

A-level PHYSICS A

Unit 5D Turning Points in Physics Section B

Tuesday 28 June 2016

Morning

Time allowed: The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 50 minutes on this section.

Materials

For this paper you must have:

- a calculator
- a pencil and a ruler
- a Data and Formulae Booklet (enclosed).

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this section is 35.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



Section B

The maximum mark for this section is 35. You are advised to spend approximately 50 minutes on this section.

- 1 (a)** J J Thomson devised the first experiments to determine the specific charge for cathode rays produced in discharge tubes. He found that the value did not depend on the gas in the tube. He also discovered that particles emitted by a heated filament and particles emitted in the photoelectric effect had the same specific charge.

State **two** conclusions that were drawn from Thomson's experiments.

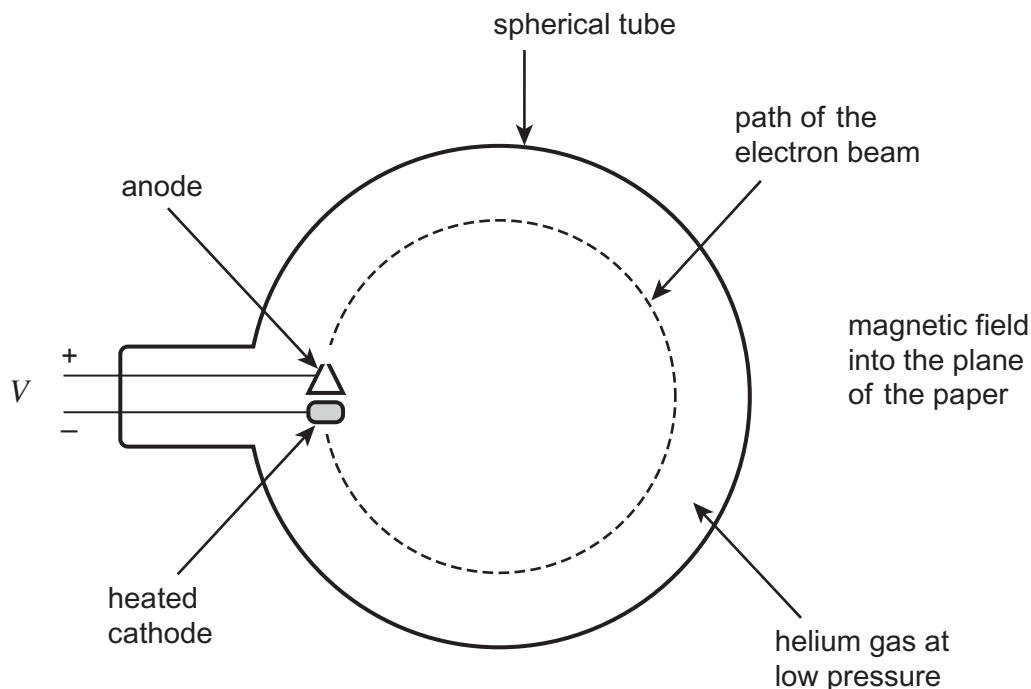
[2 marks]

1 _____

2 _____

- 1 (b)** **Figure 1** shows a spherical tube, filled with low-pressure helium gas, that is used in an experiment to determine the specific charge of an electron.

Figure 1



Electrons are accelerated by a potential difference (pd) V applied between the cathode and anode. A magnetic field of known flux density B , directed into the plane of the diagram, causes the electrons to move in a circular path.



- 1 (b) (i) Explain the process that causes the low-pressure helium gas to emit light so that the path of the electron beam can be seen.

[3 marks]

- 1 (b) (ii) In one experiment using the apparatus in **Figure 1**, the accelerating pd is 1.6 kV and the flux density of the magnetic field is 2.2 mT. The path of the electron beam has a radius of 0.059 m.

Determine a value for the specific charge of an electron using these data.
State an appropriate unit for your answer.

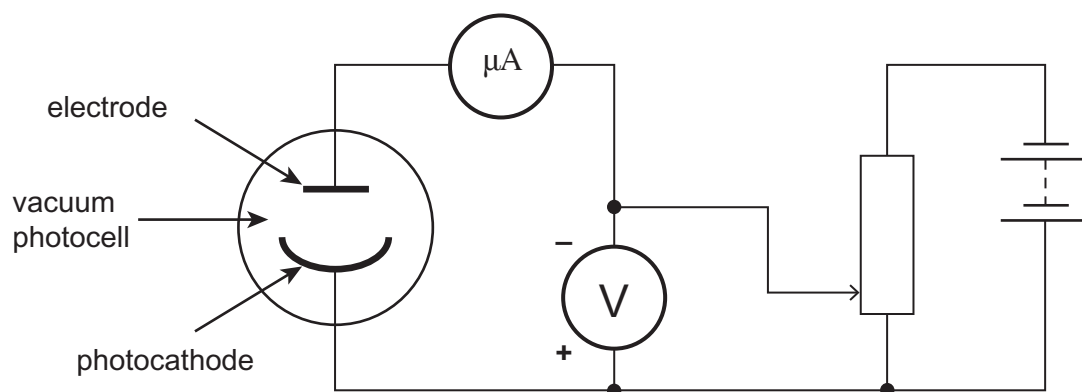
[4 marks]

specific charge = _____ unit = _____



- 2 (a)** The arrangement shown in **Figure 2** is used by a student in a photoelectric effect experiment.

Figure 2



Monochromatic light falls on the photocathode. A current is recorded when the potential difference (pd) between the photocathode and the electrode is zero.

The student gradually increases the magnitude of the pd between the photocathode and electrode and makes observations of the effect this has on the current.

Describe and explain the observations that you would expect the student to make. In your answer you should refer to:

- the stopping potential
- the kinetic energy of the photoelectrons
- how Einstein's photoelectric equation applies to this experiment.

The quality of your written communication will be assessed in your answer.

[6 marks]



Question 2 continues on the next page

2 (b) Using the circuit in **Figure 2**, the stopping potential recorded is 0.24 V when light of wavelength 490 nm is incident on the surface of the photocathode.

2 (b) (i) Calculate the work function of the surface material.

[3 marks]

work function = _____ J

2 (b) (ii) The polarity of the battery in **Figure 2** is now reversed and light of 490 nm is incident on the photocathode. The energy of the light falling on the surface of the photocathode each second is 6.1 μJ .

Calculate the maximum current that the microammeter could record.

[2 marks]

maximum current = _____ μA



Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Turn over ►



- 3 (a)** Maxwell predicted the existence of electromagnetic waves that travelled in free space.

Identify the **two** quantities that vary in an electromagnetic wave and state the phase relationship between them.

[2 marks]

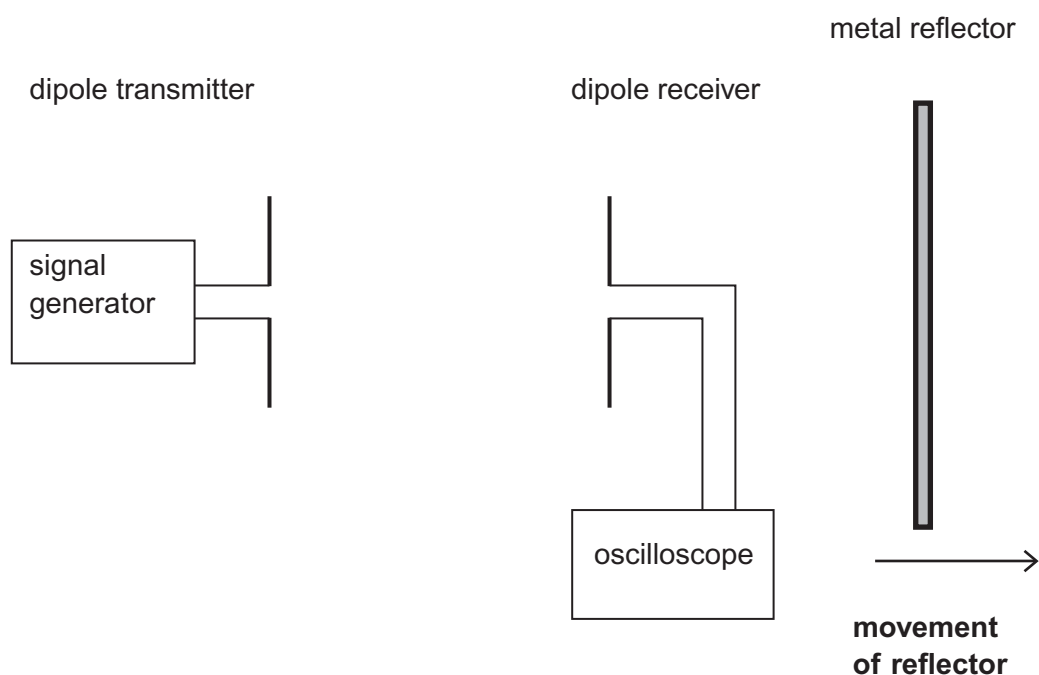
Quantity 1 _____

Quantity 2 _____

Phase relationship _____

- 3 (b)** Hertz determined the speed of electromagnetic waves and found that they travelled at $3.0 \times 10^8 \text{ m s}^{-1}$. **Figure 3** shows an arrangement using radio waves that is similar to that used by Hertz in his determination.

Figure 3



The dipole transmitter radiates an electromagnetic wave of frequency 2.2 GHz.

A signal is detected by the dipole receiver.

When the metal reflector is moved in the direction shown in **Figure 3**, the detected signal strength alternates between maximum and minimum intensities.



- 3 (b) (i)** Explain why the detected signal strength changes from a maximum to a minimum as the metal reflector is moved.

[3 marks]

- 3 (b) (ii)** Determine the least distance the reflector has to move for the detected signal strength to change from a maximum to a minimum to confirm Hertz's value for the speed of electromagnetic radiation.

[2 marks]

least distance = _____ m

- 3 (c)** Which **one** of the following observations originally led to the conclusion that light is an electromagnetic wave?

Place a tick (✓) in the right-hand column to show the correct answer.

[1 mark]

	✓ if correct
Light is diffracted when it falls on a narrow slit.	
Light travels at $3 \times 10^8 \text{ m s}^{-1}$ in free space.	
Light changes speed when it enters a medium of different optical density.	
Light can be polarised when it passes through Polaroid.	

Turn over ►



- 4 (a)** The theory of special relativity is based on two postulates. One of these postulates is that the speed of light in free space is invariant. State the other postulate.

[1 mark]

- 4 (b)** An electron in the Stanford linear accelerator is accelerated to an energy of 24.0 GeV.

- 4 (b) (i)** An electron travelling with this energy has a velocity v .

Show that the value of $\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$ is about 2.1×10^{-5} .

[3 marks]

- 4 (b) (ii)** The Stanford linear accelerator has a length of 3.0 km. Assume that the electron travels for the full length of the accelerator with an energy of 24 GeV.

Calculate the length, in m, of the accelerator in the reference frame of the electron.

[1 mark]

length of accelerator = _____ m

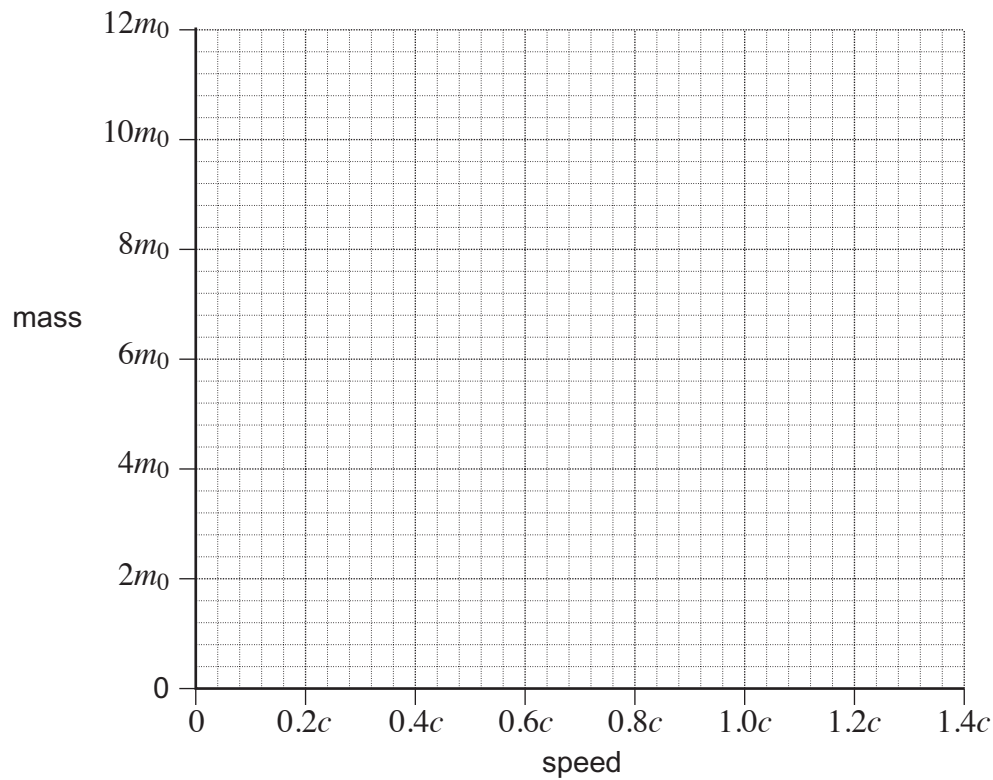


- 4 (c)** Draw a graph on **Figure 4** to show how the relativistic mass of an electron varies with speed as it is accelerated from rest.

Rest mass of an electron = m_0

[2 marks]

Figure 4



7

END OF QUESTIONS



There are no questions printed on this page

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A-level Physics

PHYA5/2D – Turning Points in Physics
Mark scheme

2450
June 2016

Version: 1.0 Final

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

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Question	Answers	Additional Comments/Guidance	Mark
1(a)	Experiments suggested cathode rays were negatively charged particles✓ Particle has mass much smaller than mass of an atom/hydrogen ion OR Compares Specific charge with that of hydrogen ion/atom✓ Particles were part of the substructure of matter/atoms✓ Particles emitted in each case were the same OR Particles emitted were the same for different gases/for photoelectrons and particles from thermionic emission✓	MAX 2 Specific charge defined =0 Millikan/Rutherford deductions=0 Do not allow small mass alone Allow proton <i>Allow two correct deductions in 1 or 2 provided that the other comment is not relevant but does not contradict,</i>	2
1(b)(i)	electrons collide with atoms of gas✓ (condone molecules) <i>Reference to collisions with nucleus = 0 for the question</i> atoms/electrons are excited or atoms /electrons change to higher energy states✓ light/photon emitted when relaxation/de-excitation occurs or as electrons move/fall back to lower energy level✓	Do not allow • collide with gas unless atoms mentioned later • particles • electrons absorbed by atoms Allow move from ground state Allow return to ground state	3

1(b)(ii)	$eV = \frac{1}{2}mv^2$ and $\frac{mv^2}{r} = Bev$ or $\frac{e}{m} = \frac{v}{Br}$ in any form ✓ or $\frac{e}{m} = \frac{2V}{B^2r^2}$ Correct substitution of data in the question allowing errors in powers of 10 ✓ 1.9×10^{11} ✓ $C \text{ kg}^{-1}$ ✓	Must be seen Substitution of values of e and m_e can gain 1 st and last marks only	4
Total			9

Question	Answers	Additional Comments/Guidance	Mark
2(a)	Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should apply a ‘best-fit’ approach to the marking.		6
	Level 0 Nothing of relevance		
	Level 1 (1—2 marks)		
	Answer is largely incomplete. It may contain valid points which are not clearly linked to an argument structure. Unstructured answer Errors in the use of technical terms, spelling, punctuation and grammar or lack of fluency		
	Level 2 (3—4 marks)		
	Answer has some omissions but is generally supported by some of the relevant points below: - the argument shows some attempt at structure - the ideas are expressed with reasonable clarity but with a few errors in the use of technical terms, spelling, punctuation and grammar		
	Level 3 (5—6 marks)		
	Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below: - argument is well structured with minimum repetition or irrelevant points - accurate and clear expression of ideas with only minor errors in the use of technical terms, spelling and punctuation and grammar		

	examples of possible points in the response Observations - Initially ammeter record current - as pd increases the current decreases - eventually current becomes 0 Emission - Photons/light cause emission of electrons - Emitted electrons have KE (if photon energy > work function) - pd tends to stop emitted electrons reaching the electrode/anode (not stop electrons being emitted) - Recognises that the electrode is negative w.r.t. the cathode or vice versa - Recognises that there are a range of electron KEs - Explains why there is a range of KEs - Electrons with low energy stopped (first) so current decreases Stopping potential - The potential between the electrodes when the current =0 - The potential that prevents electrons reaching the anode/electrode - Stopping potential depends on maximum electron KE Application of Einstein equation - Use of $E_{k(max)} = hf - \phi$ - Defines terms - Explain/identifies that stopping potential x electron charge = atoms/molecules/electrons $V_s e = E_{k(max)}$	extra information 5-6 will address 3 aspects well or all 4 with minor omissions in coherent response 3-4 will address three of the points with significant omissions or e.g, give good response to 2 parts 1-2 may give brief but relevant comments on - the emission - what is meant by stopping potential - Some attempt to apply Equation 0 makes no relevant comment	
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2(b)(i)	Kinetic energy of emitted electrons = $0.24 \times 1.6 \times 10^{-19}$ or $0.38 \times 10^{-19}(\text{J})$ seen✓ energy of photon incident = $6.63 \times 10^{-34} \times 3 \times 10^8 / 490 \times 10^{-9}$ or $4.06 \times 10^{-19}(\text{J})$ seen✓ Work function = $3.68 \times 10^{-19}(\text{J})$ ✓ Or energy of photon incident = $6.63 \times 10^{-34} \times 3 \times 10^8 / 490 \times 10^{-9} = 4.06 \times 10^{-19}(\text{J})$ ✓ (energy of photon incident = 2.54 eV so) work function = 2.30 eV ✓ Work function = $3.7 (3.68) \times 10^{-19}(\text{J})$ ✓	Must see all values substituted to get the mark by substitution	3
2(b)(ii)	No of electrons emitted = 6.1×10^{-6} / their photon energy $(1.5(1.48) \times 10^{13})$ if correct) ✓ Current = Their electron number $\times 1.6 \times 10^{-19}$ $(2.4(2.37) \mu\text{A})$ if correct) ✓	Allow for first mark only 6.16×10^{-6} / work function (1.65×10^{13}) Allow ecf for incorrect calculation of photon energy from (b)(i) or first step	2
Total			11

Question	Answers	Additional Comments/Guidance	Mark
3(a)	electric field strength and magnetic flux density/magnetic field strength✓ They are in phase with each other ✓ OR Phase difference = 0 (not 2π)	Allow E and B (not E field and B field) Not electric field and magnetic field Not allowed if quantities are mentioned are not related to electric and magnetic fields(e.g. frequency & wavelength) or no quantities given	2
3(b)(i)	Direct and reflected waves superpose/ Waves arriving directly interfere with reflected waves. Or Direct and reflected wave produce a stationary wave✓ When a maximum constructive interference or explanation of condition and minimum destructive interference or explanation of condition Or maximum/constructive interference at antinode and minimum /destructive interference at a node✓ Explains maximums/antinodes and minimums/nodes in terms of wavelengths, relative phase or path difference✓ i.e. there is constructive interference/antinode - reflected wave travels whole number of wavelengths further - path difference is whole number of wavelengths - waves are in phase destructive interference minimum/node when - the direct and reflected waves interfere destructively - the waves become antiphase/180° out of phase - path difference is $\lambda/2$ or $(n+1/2)\lambda$	Do not allow superimpose Do not allow out of phase	3

3(b)(ii)	Wavelength = $\frac{3 \times 10^8}{2.2 \times 10^9}$ or 0.136 m (0.14) seen or appreciates that the reflector has to move $\lambda/4$ ✓ 0.034 or 0.035 (m) ✓	Penalise 1 sf answer	2								
3(c)	<table><tr><td>Light is diffracted when it falls on a slit</td><td></td></tr><tr><td>Light travels as $3 \times 10^8 \text{ m s}^{-1}$ in free space</td><td>✓</td></tr><tr><td>Light changes speed when it enters a medium of different optical density</td><td></td></tr><tr><td>Light can be polarised when it is passes through polaroid</td><td></td></tr></table>	Light is diffracted when it falls on a slit		Light travels as $3 \times 10^8 \text{ m s}^{-1}$ in free space	✓	Light changes speed when it enters a medium of different optical density		Light can be polarised when it is passes through polaroid			1
Light is diffracted when it falls on a slit											
Light travels as $3 \times 10^8 \text{ m s}^{-1}$ in free space	✓										
Light changes speed when it enters a medium of different optical density											
Light can be polarised when it is passes through polaroid											
Total			11								

Question	Answers	Additional Comments/Guidance	Mark
4(a)	The laws of physics are the <u>same</u> in <u>all inertial</u> frames of reference OWTTE	Allow specified laws e.g, Newton's laws applies in all inertial frames of reference Do not allow laws of physics are obeyed or apply Allow any/every inertial frame of reference	1

4(b)(i)	Converts 24 GeV to J $24 \times 10^9 \times 1.6 \times 10^{-19}$ or 3.84×10^{-9} (J) seen✓ 3.84×10^{-9} or $24 \times 10^9 = \frac{9.11 \times 10^{-31} \times (3 \times 10^8)^2}{\gamma} (-9.11 \times 10^{-31} \times (3 \times 10^8)^2) \checkmark$ 2.14 or 2.13×10^{-5}✓ from correct working at least 3 sf needed	Many convert to equivalent mass 4.27×10^{-26} and then work in masses throughout May include the bracketed term. Depending on whether they assume 24 GeV to be the total energy or the kinetic energy Allow incorrect powers of 10 May use given γ and find energy and compare with 24 GeV	3
4(b)(ii)	$3000 \times 2.1 \times 10^{-5} = 0.063$ or 0.064 m✓		1
4(c)	Starts at m_0✓ Shallow increase to - no more than $2m_0$ at $0.7c$ - curves (sharply) upwards becoming greater than $0.9c$ at $6m_0$ - never greater than $1.0c$ - within $\frac{1}{2}$ square of $1.0c$ at $12m_0$ ✓	Never greater than $1.0c$ Allow statement of asymptote	2
Total			7

Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

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Examiner's Initials	
Question	Mark
1	
2	
3	
4	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2015

Physics A

PHYA5/2D

Unit 5D Turning Points in Physics Section B

Thursday 18 June 2015 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a pencil and a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 50 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
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 - organise information clearly
 - use specialist vocabulary where appropriate.



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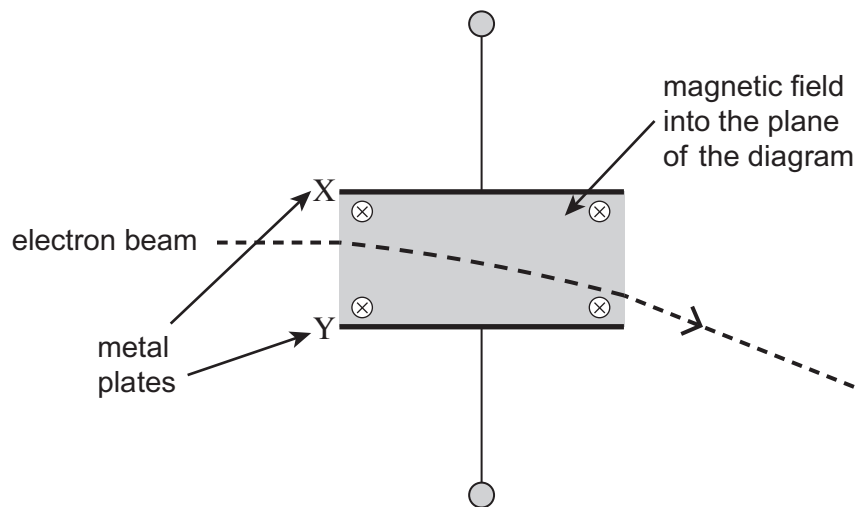
PHYA5/2D

Section B

The maximum mark for this section is 35. You are advised to spend approximately 50 minutes on this section.

- 1** **Figure 1** shows part of an evacuated tube that is used to determine the specific charge (e/m) for an electron. An electron beam is directed between the two parallel metal plates, X and Y. In the region between the plates, a magnetic field is applied perpendicularly into the plane of the diagram. An electric field can be applied in this region by applying a potential difference (pd) between the plates.

Figure 1



- 1 (a)** **Figure 1** shows the path of the electron beam when the magnetic field is applied and the pd between X and Y is zero.
- 1 (a) (i)** Explain why the path followed by the electron beam in the magnetic field is a circular arc. **[2 marks]**

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- 1 (a) (ii) Show that the speed v of the electrons is given by $v = \frac{Ber}{m}$

where r is the radius of the path of an electron in the magnetic field and B is the flux density of the magnetic field.

[1 mark]

- 1 (a) (iii) A pd V is now applied between X and Y without changing the flux density of the magnetic field. V is adjusted until the electron beam is not deflected as it travels in the region between the plates.

Determine an expression for the speed v of the electrons in terms of V , B and the separation d of the metal plates.

[1 mark]

- 1 (b) Use the equation given in part (a)(ii) and your answer to part (a)(iii) to show that the specific charge for the electron = $\frac{V}{B^2 r d}$.

[1 mark]

Question 1 continues on the next page

Turn over ►



- 1 (c)** If the charge on an electron is known then its mass can be determined from the specific charge. Describe how Millikan's experiment with charged oil droplets enables the electronic charge to be determined.

Include in your answer:

- the procedures used to determine the radius of a droplet and the charge on a droplet
- how the measurements made are used
- how the electronic charge can be deduced.

[6 marks]

The quality of your written communication will be assessed in your answer.

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Turn over ►



- 2 (a) (i)** Describe how Newton used the corpuscular theory to explain the refraction of light as it passes from one substance into a substance of higher optical density.

[3 marks]

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- 2 (a) (ii)** Huygens used a wave theory to explain refraction.

Explain why the corpuscular theory was rejected in favour of a wave theory to explain refraction.

[2 marks]

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- 2 (a) (iii)** Describe and explain the difference in the appearance of the fringes in Young's double-slit experiment that are predicted by the corpuscular theory and by the wave theory for light.

[2 marks]

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- 2 (b)** Electromagnetic waves and matter are now known to exhibit both particle and wave behaviour. The photons for a particular X-ray wavelength have energy 5.0 keV.

Calculate the potential difference through which an electron has to be accelerated so that its de Broglie wavelength is the same as that of this X-ray.

[4 marks]

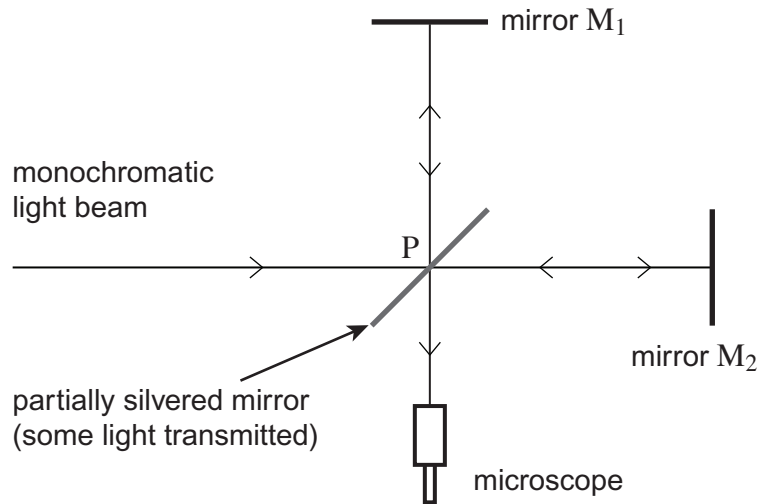
11

Turn over ►



- 3 **Figure 2** shows the paths of light rays through a simplified version of the apparatus used by Michelson and Morley.

Figure 2



In the apparatus, light waves reflected by the mirrors M_1 and M_2 , meet at P so that they superpose and produce interference fringes. These are observed using the microscope.

Michelson and Morley predicted that the fringes would shift when the apparatus was rotated through 90° . They thought that this shift would enable them to measure the speed of the Earth through a substance, called the aether, that was thought to fill space.

- 3 (a) Explain why Michelson and Morley expected that the fringe positions would shift when the apparatus was rotated through 90° .

[2 marks]

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- 3 (b)** In their apparatus they made the distances PM_1 and PM_2 the same and equal to d . They used light of wavelength (λ) about 550 nm and knew that the speed of light c was $3.0 \times 10^8 \text{ m s}^{-1}$. Using known astronomical data, they calculated the speed v at which they thought the Earth moved through the aether. They were then able to predict that when the apparatus was rotated through 90° the fringes should shift by a distance $0.4f$, where f was the fringe spacing.

- 3 (b) (i)** To determine v , Michelson and Morley assumed that the Sun was stationary with respect to the aether as the Earth moved through it. Suggest, using this assumption, how the speed v of the Earth through the aether could be determined. You do not need to do the calculation.

[1 mark]

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- 3 (b) (ii)** Michelson and Morley calculated v to be $3.0 \times 10^4 \text{ m s}^{-1}$. They worked out Δf , the magnitude of the expected shift of the fringes, using the formula $\Delta f = \frac{2v^2 d}{c^2 \lambda} f$.

Calculate the distance d they used in their experiment.

[1 mark]

$d = \dots\dots\dots \text{ m}$

Question 3 continues on the next page

Turn over ►



- 3 (c)** Although a shift of $0.4f$ was easily detectable, no shift was observed. Explain what this null result demonstrated and its significance for Einstein in his special theory of relativity. **[2 marks]**

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6



- 4** A muon is an unstable particle produced by cosmic rays in the Earth's atmosphere. Muons that are produced at a height of 10.7 km above the Earth's surface, travel at a speed of $0.996c$ toward Earth, where c is the speed of light. In the frame of reference of the muons, the muons have a half-life of 1.60×10^{-6} s.

- 4 (a) (i)** Calculate how many muons will reach the Earth's surface for every 1000 that are produced at a height of 10.7 km.

[3 marks]

number of muons

- 4 (a) (ii)** Which of the following statements is correct? Tick (✓) the correct answer.

[1 mark]

	✓ if correct
For an observer in a laboratory on Earth, the distance travelled by a muon that reaches the Earth is greater than the distance travelled by a muon in its frame of reference	
For an observer in a laboratory on Earth, time passes more slowly than it does for a muon in its frame of reference	
For an observer in a laboratory on Earth, the probability of a muon decaying each second is lower than it is for a muon in its frame of reference	

Question 4 continues on the next page

Turn over ►



- 4 (b) (i) Show that the total energy of an electron that has been accelerated to a speed of $0.98c$ is about $4 \times 10^{-13} \text{ J}$.

[2 marks]

- 4 (b) (ii) The total energy of an electron travelling at a speed of $0.97c$ is $3.37 \times 10^{-13} \text{ J}$. Calculate the potential difference required to accelerate an electron from a speed of $0.97c$ to a speed of $0.98c$.

[1 mark]

potential difference = ... V

7

END OF QUESTIONS



A- LEVEL

Physics

PHA5/2D – Turning Points in Physics
Mark scheme

2450
June 2015

Version/Stage: v1 Final

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Further copies of this mark scheme are available from aqa.org.uk

Question	Answers	Additional Comments/Guidance	Mark	ID details
1(a)(i)	There is a (constant) force acting which is (always) at right angles/perpendicular to the path/motion/velocity/direction of travel/to the beam Or mentions a centripetal force✓ Force is at right angles to the magnetic field <u>and</u> the electron motion Or <u>direction</u> given by left hand rule✓	First mark is for condition for circular motion Not speed Second mark is for a statement relating to the origin of the force Any mention of attraction to the plates is talk out (TO)	2	
1(a)(ii)	States $Bev = \frac{mv^2}{r}$ and evidence of correct intermediate stage showing manipulation of the formula or Quotes $r = \frac{mv}{Be}$ from formula sheet and change of subject to $v = Ber/m$ seen	Accept delete marks or rewrite as $Be = \frac{mv}{r}$ or rearrangement as $\frac{v^2}{v} = \frac{Ber}{m}$	1	
1(a)(iii)	States $Bev = \frac{eV}{d}$ or $F = Bev$ $F = \frac{eV}{d}$ (or $F = Ee$ and $E = \frac{V}{d}$ in any form) <u>and</u> states $v = \frac{V}{Bd}$✓	Allow use of e or Q No mark for just quoting final equation. There must be evidence of useful starting equations	1	

1(b)	Equates the formulae for v and shows $\frac{e}{m}$ equated to $\frac{V}{B^2 r d}$	Must include 'e/m = 'not just 'specific charge ='	1	
		Note there is no ecf. Candidates who use an incorrect equation in 1a(iii) will lose this mark unless they restart from first principles. Condone Q/m		
1(c)	Using band marking Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should apply a 'best-fit' approach to the marking. Level 1 (1-2 marks) Answer is largely incomplete. It may contain valid points which are not clearly linked to an argument structure. Unstructured answer Errors in the use of technical terms, spelling, punctuation and grammar or lack of fluency Level 2 (3—4 marks) Answer has some omissions but is generally supported by some of the relevant points below: - the argument shows some attempt at structure - the ideas are expressed with reasonable clarity but with a few errors in the use of technical terms, spelling, punctuation and grammar Level 3 (5—6 marks) Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below:		6	

	- argument is well structured with minimum repetition or irrelevant points - accurate and clear expression of ideas with only minor errors in the use of technical terms, spelling and punctuation and grammar A Measure the terminal speed of the falling droplet At the terminal speed weight = viscous force (+ upthrust) $mg = 6\pi\eta rv \text{ and } m = 4\pi r^3 \rho / 3 \text{ so } r^2 = \frac{9\eta v}{2\rho g}$ r could be determined as density of drop, viscosity of air and g are known (r is the only unknown) B m can be determined if r is known Apply pd between the plates so electric field = V/d and adjust until droplet is stationary $QV/d = mg$ so Q can be found C Make a number of measurements to find Q Results for Q are in multiples of $1.6 \times 10^{-19} \text{C}$ so Q can be found	e.g. 1-2 Superficial with some sensible comments about the procedure with significant errors in attempts at use of equations. May do one part of A B or C reasonably well. Relevant Equations without little explanation may be worth 1. 3-4 Should cover most of the point in two of A, B & C coherently A & B may be well done in an answer that is easy to follow or B and C may be well explained but there may be significant errors or omissions in the determination of r. or a bit of all A B and C with significant errors or omissions 5-6 Will cover the points made in A B & C with few omissions in an answer that is easy to follow. The candidate will define some terms used in		
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		equations. 1-2 Attempt to explain how to determine radius with detail of how to use data or Makes a relevant point about some part of the procedure about the determination 3-4 radius determination explained with sensible equations explanation of how to use data to find mass of the drop Idea of holding the drop stationary 5-6 Answer includes all steps to determine the charge of a droplet with correct equations showing how to use the measurements For highest mark the answer should include idea of interpreting results of many measurements		
Total			11	

Question	Answers	Additional Comments/Guidance	Mark	ID details
2(a)(i)	Appreciation that one component changes speed while the other component at right angles does not✓ When entering a denser medium a corpuscle /light accelerates or its velocity/momentum increases <u>perpendicular to the interface</u> ✓ There is a (short range) attractive force between light <u>corpuscle</u> and the (denser) material✓	Not allowed: Attraction due to opposite charges Force making them move faster is not enough Accelerate in medium Not gains energy	3	
2(a)(ii)	Light (was shown by experiment to) travel slower in (optically)denser medium OWTTE✓ Newton's theory required light to travel faster, wave theory suggested slower speed✓ or Newton's theory could not explain the slower speed or Huygens theory could explain the slower speed	Condone 'waves..' instead of 'light' OWTTE e.g. speed in vacuum higher than speed in other medium Not allowed: Reference to Young's two slit- question asks them about refraction.	2	
2(a)(iii)	A corpuscular theory predicts only two (bright) lines/high intensity patches of light whereas a wave theory predicts many fringes✓ Corpuscles can only travel in straight lines or waves can produce fringes because (diffract and) interfere/superpose/ arrive in and out of phase/have different path differences ✓	Need to describe the patterns ie not just interference fringes are seen for the first mark	2	

2(b)	Substitutes data in photon wavelength = hc/E ; Allow for substitution with no conversion to J ✓ $2.48 \times 10^{-10} \text{ m}$ ✓ For electron: Substitution in $\lambda = \frac{h}{\sqrt{2mE}}$ 2.48×10^{-10} (or their λ) $= 6.6 \times 10^{-34} / (2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \text{ V})^{1/2}$ ✓ $V = 24(.4) \text{ V}$ ✓ $= 1.49 \times 10^{-18} / (\text{their } \lambda)^2$ ✓ May calculate v using $v = h/m\lambda$ then substitution in $V = \frac{1}{2} mv^2/e$ ✓ (for third mark)	No conversion to J gives $\lambda \approx 4 \times 10^{-29}$ and $V \approx 9 \times 10^{38} \text{ V}$ Allow small rounding errors in dp	4	
Total			11	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3(a)	They expected the time taken for the light to travel in one direction to be different from the other ✓ or Expected light to travel at different speeds in the two directions There would be a phase shift /change in the phase relationship	However expressed e.g. in terms of the different times taken parallel and at right angles to the Earth's motion (through the Aether) Not longer/different paths or path difference	2	

3(b)(i)	speed through aether $= \frac{\text{circumference of Earth orbit around the Sun}}{\text{time for one orbit (1 year)}}$ or $v = (GM/r)^{1/2}$ with M and r defined	Need to be clear about the distance and time. Watch out for confusion between Earth's orbit around the Sun and Earth's rotation on its axis	1	
3(b)(ii)	11 m		1	
3(c)	Experiment showed speed of light from moving object is same as that from stationary object or Speed of light in direction of motion is same as in perpendicular direction or speed of light does not depend on speed of source or observer Speed of light being invariant or Aether theory incorrect/no aether/no absolute motion It was a postulate/assumption of the theory of special relativity Or this supports the theory✓	Allow is always $3 \times 10^8 \text{ m s}^{-1}$ in air or vacuum instead of invariant Second mark is for <u>explicitly</u> linking the observation to Einstein's theory	2	
Total			6	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4(a)(i)	Distance travelled in muons' frame of reference $= 10700(1-0.996^2)^{1/2} = 956 \text{ m} \checkmark$ Time taken in muons' frame of reference $= 3.2 \text{ } \mu\text{s} \checkmark$ This is 2 half-lives so number reaching Earth $= 250 \checkmark$ OR Time in Earth frame of reference $= 10700/(0.996 \times 3 \times 10^8) = 3.581 \times 10^{-5} \text{ s} \checkmark$ Time taken in muons' frame of reference $= 3.2 \text{ } \mu\text{s} \checkmark$ This is 2 half-lives so number reaching Earth $= 250 \checkmark$ OR Half-life in Earth frame of reference $= 1.6 \times 10^{-6}/(1-0.996^2)^{1/2} = 17.9 \times 10^{-6} \text{ s} \checkmark$ Time taken $= 35.8 \times 10^{-6} \text{ s} \checkmark$ This is 2 half lives so number reaching Earth $= 250 \checkmark$ OR Distance travelled in muons' frame of reference $= 10700(1-0.996^2)^{1/2} = 956 \text{ m} \checkmark$ Distance the muon travels in one half-life in muons reference frame $= 0.996 \times 3 \times 10^8 \times 1.6 \times 10^{-6} = 478 \text{ m} \checkmark$ Therefore 2 half-lives elapse to travel 956 m so number $= 250 \checkmark$ OR decay constant in muon frame of reference or decay constant in the Earth frame of reference $\checkmark$ Uses the corresponding elapsed time and decay constant in $N = N_0 e^{-\lambda t} \checkmark$ Arrives at 250 $\checkmark$	All steps in the working must be seen Award marks according to which route they appear to be taking. The number left must be deduced from the correct time that has elapsed in the frame of reference they are using.	3	

4(a)(ii)		✓ if correct		1	
	For an observer in a laboratory on Earth the distance travelled by a muon is greater than the distance travelled by the muon in its frame of reference	✓			
	For an observer in a laboratory on Earth time passes more slowly than for a muon in its frame of reference				
	For an observer in a laboratory on Earth, the probability of a muon decaying each second is lower than it is for a muon in its frame of reference				
4(b)(i)	Total energy = $9.11 \times 10^{-31} \times (3 \times 10^8)^2 / (1 - 0.98^2)^{1/2}$ ✓ $4.12 \times 10^{-13} \text{ J}$ seen to 2 or more sf ✓		Show that so working must be seen	2	
4(b)(ii)	Change = $7.5 \times 10^{-14} \text{ J}$ $V = 469 \text{ (470) kV}$ allow ecf using their answer to (b)(i) ✓		ecf is their ((b)(i) -3.37×10^{-13}) / 1.6×10^{-19} Using 4×10^{-13} gives 394 (390) kV Using 3.9×10^{-13} gives 331 (330) kV Do not allow 1 sf answer	1	
Total				7	

Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2014

Physics A

PHYA5/2D

Unit 5D Turning Points in Physics Section B

Thursday 19 June 2014 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 50 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this section is 35.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



J U N 1 4 P H Y A 5 2 D 0 1

WMP/Jun14/PHYA5/2D/E5

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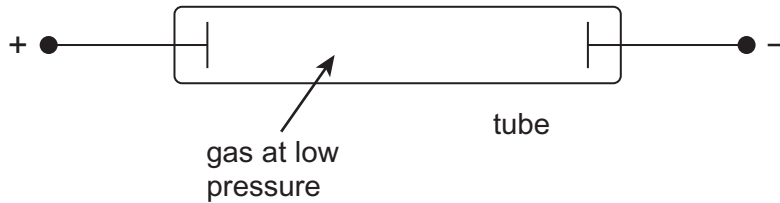
PHYA5/2D

Section B

The maximum mark for this section is 35. You are advised to spend approximately 50 minutes on this section.

- 1** **Figure 1** shows a discharge tube containing a gas at low pressure. When a sufficiently high potential difference is applied between the two electrodes in the tube the gas becomes conducting and emits light.

Figure 1



- 1 (a) (i)** Describe how the charged particles responsible for conduction in the gas are produced.

[2 marks]

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- 1 (a) (ii)** Explain why the gas emits light and why it must be at low pressure.

[3 marks]

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- 1 (b) The charged particles moving towards the negative electrode were initially referred to as positive rays. Explain why their **specific charge** depends on the choice of gas in the tube.

[2 marks]

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7

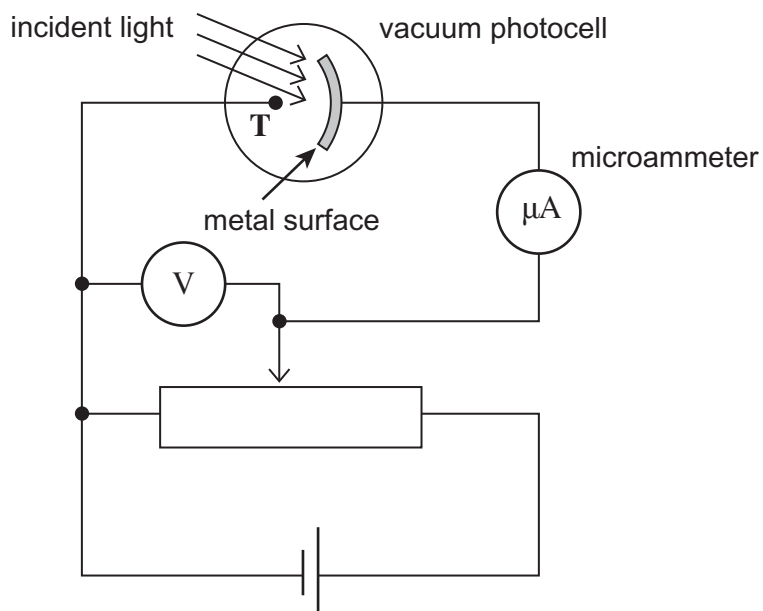
Turn over for the next question

Turn over ►



- 2** **Figure 2** shows a metal surface in a vacuum photocell illuminated by light of a certain frequency. Electrons emitted from the metal surface are collected by terminal **T** in the photocell.

Figure 2



- 2 (a)** The potential of the metal surface may be changed by adjusting the potential divider. Explain why the microammeter reading decreases when the metal surface is made more positive relative to **T**.

[3 marks]

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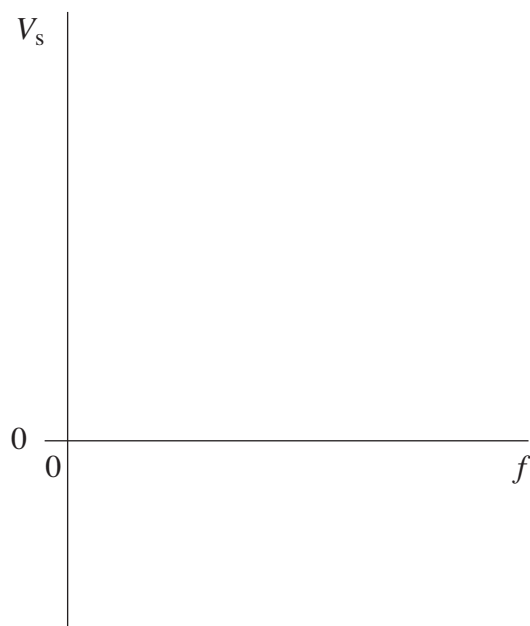
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- 2 (b)** The stopping potential V_s is the minimum potential that is applied to the metal surface to reduce the photoelectric current to zero when monochromatic light is incident on the surface. The circuit is used with light of different frequencies to measure the stopping potential V_s when the surface is illuminated at each frequency.

- 2 (b) (i)** Draw a graph on the axes below to show how V_s varies with the frequency f of the incident light.

[2 marks]



- 2 (b) (ii)** Use the photoelectric equation $hf = \phi + E_k$ to explain your graph.

[3 marks]

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Question 2 continues on the next page

Turn over ►



- 2 (c)** Using the circuit in **Figure 2**, the stopping potential was 1.92 V for light of wavelength 418 nm.
Use this information to calculate the work function of the metal surface.
Give an appropriate unit in your answer.

[4 marks]

work function unit

12



3 (a) A transmission electron microscope (TEM) contains magnetic lenses that form an image of a thin sample when a beam of electrons passes through the sample.

3 (a) (i) Explain why a magnetic lens deflects the electrons without changing their kinetic energy.

[2 marks]

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3 (a) (ii) Calculate the de Broglie wavelength of the electrons in the beam of a TEM in which the anode potential is 21 kV.
Give your answer to an appropriate number of significant figures.

[3 marks]

wavelength m

Question 3 continues on the next page

Turn over ►



- 3 (b)** In the operation of a TEM, electrons pass through a thin sample and form a magnified image of the sample on a fluorescent screen.

Describe the physical processes that the electrons are subjected to between the sample and the screen. In your account, you should discuss the relevant particle-like and wave-like properties of electrons in relation to

- the sample
- the deflection and focusing of the electron beam
- the screen
- the magnification and the quality of the image.

The quality of your written communication will be assessed in your answer.

[6 marks]

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Turn over for the next question

Turn over ►



- 4 (a)** One of the two postulates of Einstein's theory of special relativity is that physical laws have the same form in all inertial frames of reference. Explain in terms of velocity what is meant by an inertial frame of reference.

[1 mark]

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- 4 (b)** Light takes 4.3 years to reach the Earth from the star Alpha Centauri.

- 4 (b) (i)** A space probe is to be sent from the Earth to the star to arrive 5.0 years later, according to an observer on Earth. Assuming the space probe's velocity is constant, calculate its speed in m s^{-1} on this journey.

[1 mark]

speed m s^{-1}

- 4 (b) (ii)** Calculate the time taken for this journey in years registered by a clock in the space probe.

[3 marks]

time taken years

END OF QUESTIONS



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ANSWER IN THE SPACES PROVIDED**



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ANSWER IN THE SPACES PROVIDED**



A-LEVEL PHYSICS A

PHYA5/2D – Turning points in Physics
Mark scheme

2450
June 2014

Version 1.0 Final

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from aqa.org.uk

Question	Part	Sub-part	Marking guidance	Mark	Comment
1	a)	(i)	Electrons pulled out of (gas) atoms so (gas) atoms become (+) ions OR ionisation by collision (also) occurs OR (+) ions (that) hit cathode causing it to release electrons ✓ conduction due to electrons and <u>positive</u> ions ✓	2	; Allow 'electrons ionise atoms' as compensation mark (if no marks elsewhere)
1	a)	(ii)	ions and electrons (moving in opposite directions) collide (with each other) and recombine and emit photons ✓ electrons excite gas atoms (by collision) and photons are emitted when de-excitation occurs ✓ gas needs to be at sufficiently low pressure in order that the particles (or uncharged gas atoms/ions/electrons) in the gas are widely spaced ✓ otherwise (+) ions and/or electrons/particles would be stopped by gas atoms OR so that ions/electrons are accelerated (or gain enough ke) to cause excitation ✓	3max	Owtte If light not photons given in 1 st 2 mark points, 1 max for 1 st two mark points Owtte

1	b)		Specific charge = charge / mass (and charge(s) of ion does not depend on the type of gas) ✓ Mass of ion depends on the type of gas ✓	2	Accept Q/m in symbols Q/m but not e/m if e/m is specifically stated as specific charge
2	a)		emitted electrons have a range of speeds ✓ (electrostatic) force acting on electrons emitted from surface increases OR pull/attraction on electrons from surface increases ✓ microammeter reading due to electrons reaching T (moving round circuit) ✓ (microammeter reading decreases because) electrons unable to reach T due to increasing force(or insufficient ke or too much work needed) ✓	3max	Alternative for last point ; (microammeter reading decreases because) fewer electrons can reach T as pd increases,
2	b)	(i)	Graph ; straight line with a positive gradient ✓ intercept on + x-axis (or on – y-axis if drawn) ✓	2	Need to see 1 st point to get the 2 nd point
2	b)	(ii)	$E_{K(max)} = eV_S$ (or $E_{K(max)}$ proportional to V_S) ✓ gives $eV_S = hf - \phi$ where hf = photon energy and ϕ = work function of metal ✓ Graph of V_S against f is a straight line with gradient h/e ✓ and x-intercept = ϕ / h (or y-intercept = $-\phi / e$) ✓	3 max	Alt for 2nd mark; recognition that $V_S = \frac{hf}{e} - \frac{\phi}{e}$ where ϕ = work function of metal so this is equation for st line (or $y = mx + c$) Accept either of last 2 marks if shown on the graph clearly

2	c)		$hf = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{418 \times 10^{-9}} = 4.76 \times 10^{-19} \text{ J } \checkmark$ $E_{K(\max)} = eV_s = 1.6 \times 10^{-19} \times 1.92 = 3.07 \times 10^{-19} \text{ J } \checkmark$ $\phi = hf - E_{K(\max)} \text{ (or } 4.76 \times 10^{-19} - 3.07 \times 10^{-19})$ $= 1.69 \times 10^{-19} \checkmark \text{ J } \checkmark \text{ (or 1.06 eV)}$	4	Accept sub or ans for marks 1 and 2 (Ans in J ; allow 1.7 or 1.66* or 1.70 in place of 1.69) (Ans in eV ; allow 1.1 or 1.04*) *arises from rounding 3.07 to 3.1)
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3	a)	(i)	(kinetic energy is constant because) The (magnetic) force on a moving electron is always perpendicular to its velocity/direction of motion $\checkmark$ (so) no work is done on the electron (by the field) OR no acceleration in the direction of motion $\checkmark$	2	
3	a)	(ii)	$\lambda \left(= \frac{h}{\sqrt{2meV}} \right) = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 21000}} \checkmark$ $= 8.5 \times 10^{-12} \text{ m } \checkmark \text{ correct to 2sf only } \checkmark$ (Alternative ; use of $\frac{1}{2}mv^2 = eV$ gives $v = 8.59 \times 10^7 \text{ m s}^{-1} \checkmark$, and use of $\lambda = h / mv$ gives answer above $\checkmark$ correct to 2sf $\checkmark$)	3	Correct ans <u>only</u> gets 1st 2 marks (+ SF mark if SF correct) SF mark can only be given if some valid working is provided. For value of v , accept ans in range 8.5 to 8.6 to any number of sfs

3	b) QWC	Descriptor	Mark	
	Good - Excellent	The candidate provides a comprehensive and logical description of most of the physical processes that occur and recognises at least two relevant properties, including a relevant wave property and a relevant particle property. The candidate also appreciates why and where in the instrument each of these properties is relevant to the formation and quality of the image. Their answer should be well-presented in terms of spelling, punctuation and grammar.	5 or 6	

	Modest – adequate	The candidate provides a logical and coherent description of some of the physical processes that occur and includes a relevant wave property or a relevant particle property. The candidate also appreciates why and where in the instrument each of these properties is relevant to the formation and quality of the image although their explanation of why each property is relevant may be sketchy. Their answer should be adequately or well-presented in terms of spelling, punctuation and grammar.	3 or 4
	Poor to limited	The candidate recognises a wave property and/or a particle property that are relevant in the context of the instrument although they may not be able to identify where in the instrument each property is relevant. They may confuse their account with incorrect terms such as interference and refraction. Their answer may lack coherence and may contain a significant number of errors in terms of spelling and punctuation.	1 or 2
	The explanations expected in a good answer should include most of the following physics ideas A At the sample ;- 1. electrons passing through the sample are scattered/diffracted by structures in the object which is a wave property . B At the magnetic lenses 1. magnetic lenses deflect the electrons which is a particle property 2. 1st lens (condenser lens) forms electrons into a parallel beam directed at the sample 3. 2nd lens (objective) deflects and focuses the electrons to form an (intermediate) image 4. 3rd lens (magnifier) deflects and focuses the electrons to form a magnified image on the screen C At the screen 1. electrons collide with atoms of the screen and excite atoms by collision which is a particle property 2. excited atoms emit photons (so image is visible) D Image quality affected by 1. loss of ke/speed (or increase of de Broglie wavelength) in passing through image affecting deflection / focusing by magnetic lenses 2. repeat scattering/diffraction of electrons passing through the object if the object is too thick. 3. diffraction of electrons occurs as they pass through each lens 4. diffraction affects resolution of nearby image points (on the screen) 5. point objects that are too close overlap / can't be resolved		

4	a)		(A frame of reference) that has a constant velocity ✓	1	accept no acceleration
4	b)	(i)	Distance = 4.3 c light years (or 4.1×10^{16} m) Speed (= $\frac{4.3 c}{5.0}$) = $2.6 \times 10^8 \text{ m s}^{-1}$ (or 0.86 c)	1	Correct answer only gets the mark Accept 2.58
4	(b)	(ii)	$t = \left(\frac{t_0}{1 - v^2/c^2} \right)^{1/2}$ where $t = 5.0$ years (or 1.58×10^8 s) and $v = 0.86 c$ (or $2.58 \times 10^8 \text{ m s}^{-1}$) 1 st mark for correct substitution of either t or v into the above eqn ✓ $t_0 = 5.0 \times (1 - (0.86c)^2/c^2)^{1/2} \checkmark = 2.6 \text{ years } \checkmark$ Alt scheme $l = l_0 (1 - v^2/c^2)^{1/2}$ where $t = 5.0$ years (or 1.58×10^8 s) and $v = 0.86 c$ (or $2.58 \times 10^8 \text{ m s}^{-1}$) 1 st mark for correct substitution of either t or v into the above eqn ✓ $(l_0 = 4.3 \times 365 \times 24 \times 3600 \times 3.0 \times 10^8 = 4.07 \times 10^{16} \text{ m})$ $l = 4.07 \times 10^{16} (1 - (0.86c)^2/c^2)^{1/2}$ or $2.08 \times 10^{16} \text{ m} \checkmark$ $t_0 = \frac{l}{v} (= \frac{2.08 \times 10^{16} \text{ m}}{2.6 \times 10^8 \text{ m/s}} = 8.05 \times 10^7 \text{ s}) = 2.6 \text{ years } \checkmark$	3	CF from bi to bii provided answer to bi < c Accept t or v in alternative units Accept 1.58 (or 1.6) $\times 10^8$ s in place of 5.0 yr in 3rd mark point Accept 2.5 to 2.6 to any number of sfs Alternative for last 2 marks in Alt scheme $(l_0 = 4.3 \text{ l yr})$ $l = 4.3 (1 - (0.86c)^2/c^2)^{1/2} = 2.2 \text{ l yr} \checkmark$ $t_0 = \frac{l}{v} (= \frac{2.2}{0.86}) = 2.6 \text{ years } \checkmark$

Total = 35

Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2013

Physics A

PHYA5/2D

Unit 5D Turning Points in Physics Section B

Thursday 20 June 2013 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 50 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

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 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



J U N 1 3 P H Y A 5 2 D 0 1

WMP/Jun13/PHYA5/2D

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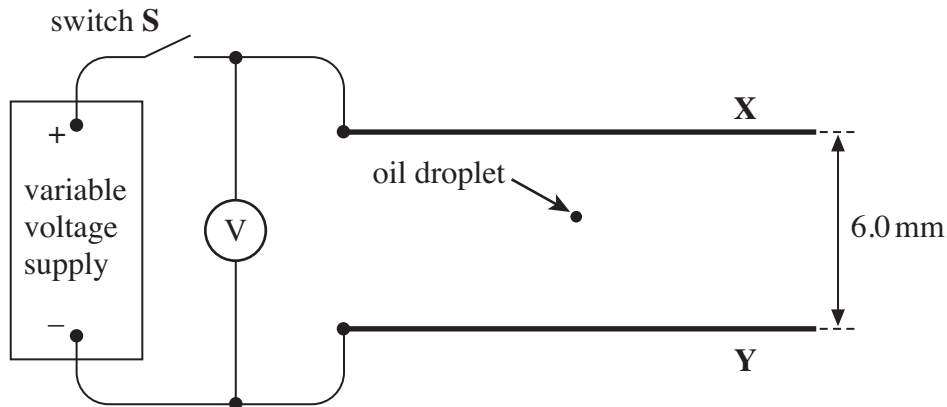
PHYA5/2D

Section B

The maximum mark for this section is 35. You are advised to spend approximately 50 minutes on this section.

- 1** A charged oil droplet was observed between two horizontal metal plates **X** and **Y**, as shown in **Figure 1**.

Figure 1



- 1 (a) (i)** With the switch **S** open, the droplet fell vertically at a constant velocity of $1.1 \times 10^{-4} \text{ m s}^{-1}$. Show that the radius of the droplet is about $1.0 \times 10^{-6} \text{ m}$. Assume the droplet is spherical.

density of oil, $\rho = 880 \text{ kg m}^{-3}$
viscosity of air, $\eta = 1.8 \times 10^{-5} \text{ N s m}^{-2}$

(4 marks)

- 1 (a) (ii)** Calculate the mass of the droplet.

mass kg
(1 mark)



- 1 (a) (iii)** The switch **S** was closed and the potential difference from the voltage supply was adjusted gradually to reduce the downward motion of the droplet. The droplet stopped moving when the potential difference across the plates was 680 V. The spacing between the plates was 6.0 mm.

Calculate the magnitude of the charge on the droplet.

charge C
(3 marks)

- 1 (b)** The mass of another charged droplet was found to be 4.3×10^{-15} kg. With switch **S** closed and the voltage supply at its maximum value of 1000 V, this droplet fell more slowly than when the switch was open but it could not be stopped.

Explain why this droplet could not be held at rest and show that the magnitude of the charge on it was 1.6×10^{-19} C.

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(4 marks)



2 (a) State de Broglie's hypothesis.

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(2 marks)

2 (b) Neutrons in a narrow beam can be diffracted by crystals thereby exhibiting wave behaviour. Calculate the de Broglie wavelength of a neutron of kinetic energy 0.021 eV. Give your answer to an appropriate number of significant figures.

de Broglie wavelength m
(4 marks)

2 (c) Explain why an electron of the same de Broglie wavelength as the neutron in part (b) has much more kinetic energy than 0.021 eV. Assume relativistic effects are negligible.

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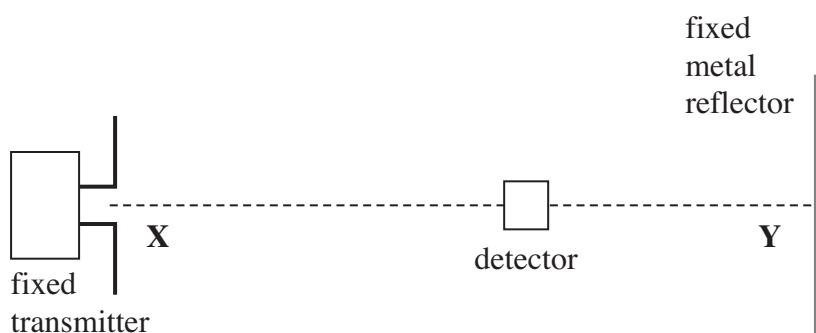
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(2 marks)



3 In his investigation of radio waves, Hertz created stationary waves by using a large flat metal sheet to reflect radio waves as shown in **Figure 2**.

Figure 2



3 (a) Explain why stationary waves are formed in this arrangement and describe how the wavelength of the radio waves can be determined by moving a suitable detector along **XY**.

The quality of your written communication will be assessed in your answer.

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the page.

(6 marks)

Turn over ►



- 3 (b)** Hertz knew the frequency of the radio waves from the electrical characteristics of the transmitter. He found the wavelength from the investigation described in part (a) and was then able to calculate the speed of the radio waves. Explain the significance of the result of this calculation.

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(2 marks)

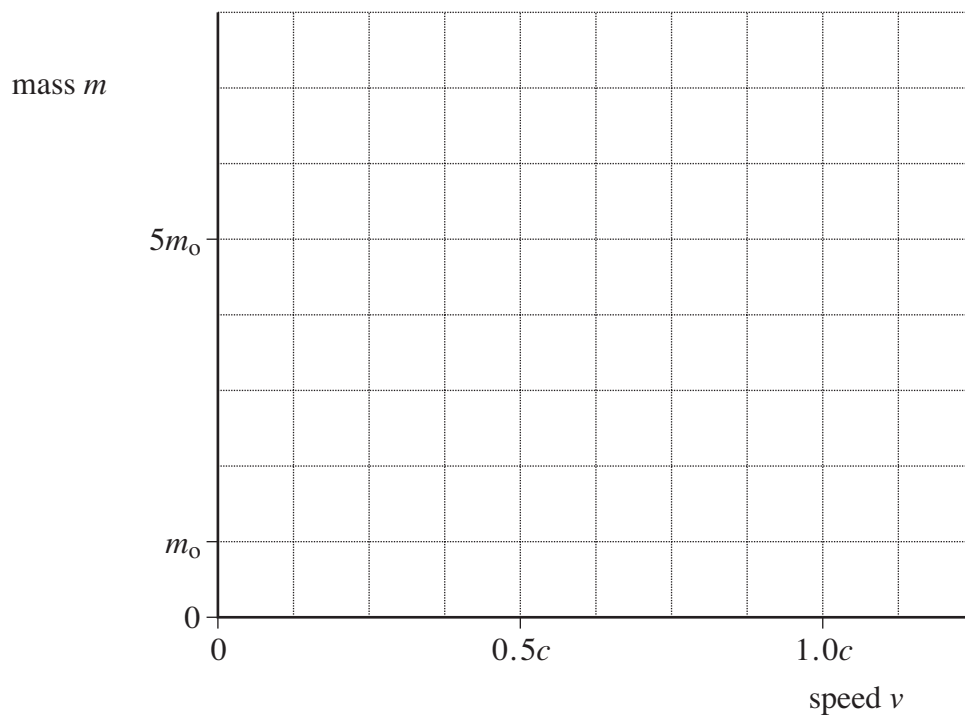
8

- 4 (a)** Calculate the speed of a particle at which its mass is twice its rest mass.

speed m s^{-1}
(2 marks)



- 4 (b)** Use the axes below to show how the mass m of a particle changes from its rest mass m_0 as its speed v increases from zero. Mark and label on the graph the point **P** where the mass of the particle is twice its rest mass.



(3 marks)

- 4 (c)** By considering the relationship between the energy of a particle and its mass, explain why the theory of special relativity does not allow a matter particle to travel as fast as light.

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(2 marks)

END OF QUESTIONS



There are no questions printed on this page

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General Certificate of Education (A-level)
June 2013

Physics A

PHA5D

(Specification 2450)

Unit 5D: Nuclear and Thermal Physics

Turning Points in Physics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

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Section A – Nuclear and Thermal Physics

Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)	(i)	1/12 the mass of an (atom) of $^{12}_6\text{C}$ / carbon-12 / C12✓	1	a reference to a nucleus loses the mark
1	(a)	(ii)	separated nucleons have a greater mass ✓ (than when inside a nucleus) because of the (binding) energy added to separate the nucleons or energy is released when a nucleus is formed (owtte) ✓	2	an answer starting with 'its' implies the nucleus marks are independent direction of energy flow or work done must be explicit
1	(b)		nuclei need to be close together (owtte) for the Strong Nuclear Force to be involved or for fusion to take place✓ but the electrostatic/electromagnetic force is repulsive (and tries to prevent this) ✓ (if the temperature is high then) the nuclei have (high) kinetic energy/speed (to overcome the repulsion) ✓	3	e.g. first mark – within the range of the SNF 3 rd mark is for a simple link between temperature and speed/KE
1	(c)	(i)	15 ✓ e^+ ✓ (or β^+ , $^0_1\beta$, ^0_1e) 12 ✓	3	give the middle mark easily for any e or β with a + in any position

1	(c)	(ii)	$\Delta\text{mass} = 4 \times 1.00728 - 4.00150 - (2 \times 9.11 \times 10^{-31} / 1.661 \times 10^{-27})$ or $\Delta\text{mass} = \{4 \times 1.00728 - 4.00150 - 2 \times 0.00055\}(\text{u}) \checkmark$ $\Delta\text{mass} = 0.02652(\text{u}) \checkmark$ $\Delta\text{binding energy} (= 0.02652 \times 931.5) \quad \{\text{allow } 931.3\}$ $\Delta\text{binding energy} = 24.7 \text{ MeV} \checkmark$	3	$(4 \times 1.00728 = 4.02912)$ 1 st mark – correct subtractions in any consistent unit. use of $m_p = 1.67 \times 10^{-27} \text{ kg}$ will gain this mark but will not gain the 2 nd as it will not produce an accurate enough result 2 nd mark – for calculated value 0.02652u $4.405 \times 10^{-29} \text{ kg}$ $3.364 \times 10^{-12} \text{ J}$ 3 rd mark – conversion to MeV conversion mark stands alone award 3 marks for answer provided some working shown – no working gets 2 marks (2sf expected)
2	(a)		insert control rods (further) into the nuclear core/reactor $\checkmark$ which will absorb (more) neutrons (reducing further fission reactions) $\checkmark$	2	a change must be implied for 2 marks marks by use of (further) or (more) allow answers that discuss shut down as well as power reduction If a statement is made that is wrong but not asked for limit the score to 1 mark (e.g. wrong reference to moderator)
2	(b)		fission fragments/daughter products or <u>spent/used</u> fuel/uranium rods (allow) plutonium (produced from U-238) $\checkmark$	1	not uranium on its own
2	(c)	(i)	γ (electromagnetic radiation is emitted) $\checkmark$ as the energy gaps are large (in a nucleus) as the nucleus de-excites down discrete energy levels to allow the nucleus to get to the ground level/state $\checkmark$ mark for reason	2	A reference to α or β loses this first mark 2 nd mark must imply energy levels or states

2	(c)	(ii)	momentum/<u>kinetic energy</u> is transferred (to the moderator atoms) or a neutron slows down/loses <u>kinetic energy</u> (with each collision) ✓ (eventually) reaching speeds associated with thermal random motion or reaches speeds which can cause fission (owtte)✓	2	
3		(i)	(heat supplied by glass = heat gained by cola) (use of $m_g c_g \Delta T_g = m_c c_c \Delta T_c$) $0.250 \times 840 \times (30.0 - T_f) = 0.200 \times 4190 \times (T_f - 3.0)$ ✓ $(210 \times 30 - 210 T_f = 838 T_f - 838 \times 3)$ $T_f = 8.4(1) (^{\circ}\text{C})$ ✓	2	1st mark for RHS or LHS of substituted equation 2nd mark for 8.4°C Alternatives: 8°C is substituted into equation (on either side shown will get mark)✓ resulting in 4620J~4190J ✓ or 8°C substituted into LHS ✓ (produces $\Delta T = 5.5^{\circ}\text{C}$ and hence) = 8.5°C ~ 8°C ✓ 8°C substituted into RHS✓ (produces $\Delta T = 20^{\circ}\text{C}$ and hence) = 10°C ~ 8°C ✓

3		(ii)	(heat gained by ice = heat lost by glass + heat lost by cola) (heat gained by ice = $mc\Delta T + ml$) heat gained by ice = $m \times 4190 \times 3.0 + m \times 3.34 \times 10^5$ ✓ (heat gained by ice = $m \times 346600$) heat lost by glass + heat lost by cola = $0.250 \times 840 \times (8.41 - 3.0) + 0.200 \times 4190 \times (8.41 - 3.0)$ ✓ (= 5670 J) $m (=5670/346600) = 0.016$ (kg) ✓ or (using cola returning to its original temperature) (heat supplied by glass = heat gained by ice) (heat gained by glass = $0.250 \times 840 \times (30.0 - 3.0)$) heat gained by glass = 5670 (J) ✓ (heat used by ice = $mc\Delta T + ml$) heat used by ice = $m(4190 \times 3.0 + 3.34 \times 10^5)$ ✓ (= $m(346600)$) $m (=5670/346600) = 0.016$ (kg) ✓	3	NB correct answer does not necessarily get full marks 3rd mark is only given if the previous 2 marks are awarded (especially look for $m \times 4190 \times 3.0$) the first two marks are given for the formation of the substituted equation not the calculated values if 8°C is used the final answer is 0.015 kg
4	(a)		molecules have negligible volume collisions are elastic the gas cannot be liquified there are no interactions between molecules (except during collisions) the gas obeys the (ideal) gas law / obeys Boyles law etc. at all temperatures/pressures any two lines ✓✓	2	a gas laws may be given as a formula
4	(b)	(i)	$n (= PV / RT) = 1.60 \times 10^6 \times 0.200 / (8.31 \times (273 + 22))$ ✓ = 130 or 131 mol ✓ (130.5 mol)	2	

4	(b)	(ii)	$\text{mass} = 130.5 \times 0.043 = 5.6 \text{ (kg)} \checkmark$ (5.61kg) $\text{density (= mass/volume)} = 5.61 / 0.200 = 28 \checkmark (28.1 \text{ kg m}^{-3})$ $\text{kg m}^{-3} \checkmark$	3	allow ecf from bi a numerical answer without working can gain the first two marks
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4	(b)	(iii)	$(V_2 = P_1 V_1 T_2 / P_2 T_1)$ $V_2 = 1.6 \times 10^6 \times .200 \times (273 - 50) / 3.6 \times 10^4 \times (273 + 22) \text{ or } 6.7(2)$ $(\text{m}^3) \checkmark$ $\text{mass remaining} = 5.61 \times 0.20 / 6.72 = 0.17 \text{ (kg)} \checkmark (0.167 \text{ kg})$ or $n = (PV / RT = 3.6 \times 10^4 \times 0.200 / (8.31 \times (273 - 50)) = 3.88(5) \text{ (mol)}$ $\checkmark$ $\text{mass remaining} = 3.885 \times 4.3 \times 10^{-2} = 0.17 \text{ (kg)} \checkmark$ 2 sig figs $\checkmark$	3	allow ecf from bii [reminder must see bii] look out for any 2 sf answer gets the mark
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5		The mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC).		
	QWC	Descriptor	Mark range	
	High Level (Good to excellent)	The candidate refers to all the necessary apparatus and records the count-rate at various distances (or thicknesses of absorber). The background is accounted for and a safety precaution is taken. The presence of an α source is deduced from the rapid fall in the count rate at 2 – 5 cm in air. The presence of a γ source is deduced from the existence of a count-rate above background beyond 30 -50 cm in air (or a range in any absorber greater than that of beta particles, e.g. 3 – 6 mm in Al) or from the intensity in air falling as an inverse square of distance or from an exponential fall with the thickness of a material e.g. lead. <i>The information should be well organised using appropriate specialist vocabulary. There should only be one or two spelling or grammatical errors for this mark.</i>	5-6	If more than one source is used or a different experiment than the question set is answered limit the mark to 4

	Intermediate Level (Modest to adequate)	The candidate refers to all the necessary apparatus and records the count-rate at different distances (or thicknesses of absorber). A safety precaution is stated. The presence of an α source is deduced from the rapid fall in the count rate at 2 – 5 cm in air and the γ source is deduced from the existence of a count-rate beyond 30 -50 cm in air (or appropriate range in any absorber, e.g. 3 -6 mm in Al). Some safety aspect is described. One other aspect of the experiment is given such as the background. <i>The grammar and spelling may have a few shortcomings but the ideas must be clear.</i>	3-4	To get an idea of where to place candidate look for 6 items: 1. Background which must be used in some way either for a comparison or subtracted appropriately 2. Recording some data with a named instrument
	Low Level (Poor to limited)	The candidate describes recording some results at different distances (or thicknesses of absorber) and gives some indication of how the presence of α or γ may be deduced from their range. Some attempt is made to cover another aspect of the experiment, which might be safety or background. <i>There may be many grammatical and spelling errors and the information may be poorly organised.</i>	1 - 2	3. Safety reference appropriate to a school setting – not lead lined gown for example 4. Record data with more than one absorber or distances 5. α source determined from results taken 6. γ source determined
		The description expected in a competent answer should include a coherent selection of the following points. apparatus: source, lead screen, ruler, γ ray and α particle detector such as a Geiger Muller tube, rate-meter or counter and stopwatch, named absorber of varying thicknesses may be used. safety: examples include, do not have source out of storage longer than necessary, use long tongs, use a lead screen between source and experimenter. measurements: with no source present switch on the counter for a fixed period measured by the stopwatch and record the number of counts or record the rate-meter reading with the source present measure and record the distance between the source and detector (or thickness of absorber) then switch on the counter for a fixed period measured by the stopwatch and record the number of counts or record the rate-meter reading repeat the readings for different distances (or thicknesses of absorber).		from results taken this is a harder mark to achieve it may involve establishing an inverse square fall in intensity in air or an exponential fall using thicknesses of lead if a continuous distribution is not used an absorber or distance in air that would just eliminate β (30-50cm air / 3-6mm Al) must be used with and without the source being present or compared to background

		use of measurements: for each count find the rate by dividing by the time if a rate-meter was not used subtract the background count-rate from each measured count-rate to obtain the corrected count-rate longer recording times may be used at longer distances (or thickness of absorber). plot a graph of (corrected) count-rate against distance (or thickness of absorber) or refer to tabulated values plot a graph of (corrected) count-rate against reciprocal of distance squared or equivalent linear graph to show inverse square relationship in air analysis: the presence of an α source is shown by a rapid fall in the (corrected) count-rate when the source detector distance is between 2 – 5 cm in air the presence of a γ source is shown if the <u>corrected</u> count-rate is still present when the source detector distance is greater than 30 cm in air (or at a range beyond that of beta particles in any other absorber, e.g. 3 mm in Al) the presence of a γ source is best shown by the graph of (corrected) count-rate against reciprocal of distance squared being a straight line through the origin		
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Section B – Turning Points in Physics

Question	Part	Sub-part	Marking guidance	Mark	Comment
1	(a)	(i)	(at terminal velocity v), weight of droplet (or mg) = viscous drag (or $6\pi\eta r v$) ✓ mass (m) of droplet = $(4\pi r^3 / 3) \times \rho$, (where r is the droplet radius) ✓ (therefore) $(4\pi r^3 / 3) \times \rho g = 6\pi\eta r v$ (or rearranged) ✓ (hence) $r = (9 \eta v / 2 \rho g)^{1/2}$ $= \frac{9 \times 1.8 \times 10^{-5} \times 1.1 \times 10^{-4}}{2 \times 880 \times 9.8}$ gives $r = 1.0(3) \times 10^{-6} \text{ m}$ ✓ note; some evidence of calculation needed to give final mark	4	<i>Backward working 3 marks max</i> ; viscous force (= $6\pi\eta r v$) = $6\pi \times 1.8 \times 10^{-5} \times 1.0 \times 10^{-6} \times 1.1 \times 10^{-4} = 3.7 \times 10^{-14} \text{ N}$ ✓ weight = $mg =$ $\frac{4}{3} \pi (1.0 \times 10^{-6})^3 \times 880 \times 9.8 = 3.6 \times 10^{-14} \text{ N}$ ✓ (allow 3.7) (therefore) viscous force = weight as required for constant velocity ✓ Allow final answer for r in the range 1 to 1.05×10^{-6} to any number of sig figs
1	(a)	(ii)	$m = ((4\pi r^3 / 3) \times \rho) = \frac{4}{3} \pi (1.0 \times 10^{-6})^3 \times 880 = 3.7 \times 10^{-15} \text{ kg}$ ✓ (or correct calculation of $6\pi\eta r v / g$)	1	Allow ecf for r from a(i) in a correct calculation that gives m in the range 3.6 to $4.0 \times 10^{-15} \text{ kg}$

1	(a)	(iii)	electric force (or QV/d) = droplet weight (or mg) ✓ $Q = \left(\frac{mgd}{V} \right) = \frac{3.7 \times 10^{-15} \times 9.8 \times 6.0 \times 10^{-3}}{680} \checkmark$ [or Q (= viscous force $\times d / V$) $= 6\pi \times 1.8 \times 10^{-5} \times 1.0 \times 10^{-6} \times 1.1 \times 10^{-4} \times 6.0 \times 10^{-4} / 680 \checkmark]$ $Q = 3.2 \times 10^{-19} \text{ C } \checkmark$	3	Allow ecf m (or r) from a(ii) (or a(i)). Accept values in 1st mark line Use of e instead of Q or q = 2 marks max For the 2nd mark, allow use of viscous force calculation. Use of viscous force method does not get 1st mark. If both methods are given and only one method gives $Q = ne$ (where n = integer >1), ignore other method for 2nd mark and 3rd mark. For the final mark, Q must be within $n e \pm 0.2 \times 10^{-19}$ from a correct calculation.
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1	(b)	The weight of the second droplet is greater than the maximum electric force on it ✓ Alternative for 1st mark ; weight = drag force + elec force (owtte) Scheme using V for next 5 marks ; If $n=1$ for the second droplet , pd to hold it = 1580 V (= mgd/e) ✓ which is not possible as $V_{\text{max}} = 1000 \text{ V}$ ✓ If $n = 2$, it would be held at rest by a pd of 790 V (= $1580/2$ or $680 \times 4.3 / 3.7 \text{ V}$) ✓ if $n > 2$, it would be held at rest by a pd of less than 790 V (or $790/n \text{ V}$) ✓ So $n=1(e)$ must be the droplet charge ✓	Max 4	Alternative schemes for last 5 marks Q scheme Using $QV/d = mg$ for a stationary droplet gives $Q = mgd/V = 2.53 \times 10^{-19} \text{ C}$ ✓ which is not possible as $Q = \text{integer} \times e$ ✓ (so) $Q (=ne) < 2.53 \times 10^{-19} \text{ C}$ ✓ owtte) Calculation to show $Q = 1e$ fits above condition ✓ $Q = 2e$ does not fit above condition ✓ F scheme;- Calc of mg to give $4.2 (\pm 0.2) \times 10^{-14} \text{ N}$ ✓ Calc for $Q = 1e$ of QV/d to give $2.6(\pm 0.2) \times 10^{-14} \text{ N}$ ✓ Calc for $Q = 2e$ of QV/d to give $5.3 (\pm 0.2) \times 10^{-14} \text{ N}$ ✓ $mg > \text{elec force for } Q = 1e \text{ or } < 2e \text{ for } Q = 2e$ ✓ So $n=1(e)$ must be the droplet charge ✓
2	(a)	(Matter) particles have wave-like properties (owtte) ✓ and an associated wavelength = h/p where p is the momentum of the particles ✓.	2	Accept mv or mass x velocity in place of p Accept 'inversely proportional to momentum (or mv)' after 'wavelength'

2	(b)	$E_K (= 0.021 \text{ eV}) = 0.021 \times 1.60 \times 10^{-19} \text{ or } 3.36 \times 10^{-21} \text{ J } \checkmark$ (Using $E_K = \frac{1}{2} m v^2$ gives) $mv = (2 m E_K)^{1/2} = (2 \times 1.67(5) \times 10^{-27} \times 3.36 \times 10^{-21})^{1/2}$ $(= 3.35 \times 10^{-24} \text{ kg m s}^{-1}) \checkmark$ [OR $v = (2 E_K / m)^{1/2} = (2 \times 3.36 \times 10^{-21} / 1.67(5) \times 10^{-27})^{1/2}$ $(= 2.0 \times 10^3 \text{ m s}^{-1})$ $mv = (1.67(5) \times 10^{-27} \times 2.0 \times 10^3 (= 3.35 \times 10^{-24} \text{ kg m s}^{-1})]$ $\lambda = \frac{h}{mv} (= \frac{6.63 \times 10^{-34}}{3.35 \times 10^{-24}}) = 1.88 \times 10^{-10} \text{ m } \checkmark$ $= 2.0 \times 10^{-10} \text{ m to 2 sf } \checkmark$	4	For 2nd mark, allow individual values of e and V in place of E_K value in data substitution For 3rd mark, allow individual values of m and v in denominator Alternative ; Correct use of 0.021 eV in $\lambda = h / (2meV)^{1/2} \checkmark$ $= \frac{6.63 \times 10^{-34}}{(2 \times 1.67(5) \times 10^{-27} \times 0.021 \times 1.6 \times 10^{-19})^{0.5}} \checkmark$ $= 1.88 \times 10^{-10} \text{ m } \checkmark = 2.0 \times 10^{-10} \text{ m to 2 sf } \checkmark$ Final sf mark - need to see some valid working
2	(c)	electron's momentum (p) is the same (as that of the neutron) and its mass is (much) smaller than neutron mass $\checkmark$ kinetic energy = $p^2 / 2m$ so kinetic energy of electron is (much) greater $\checkmark$ <u>Alternative for 2nd mark</u> :- (so) electron's speed is (much) greater and as kinetic energy = $\frac{1}{2} mv^2$, the electron's kinetic energy is (much) greater as v^2 is more significant than m (here)(owtte)	2	<u>2nd alternative for 2nd mark using $\lambda = h / (2 m E_K)^{1/2}$</u> $\lambda = h / (2 m E_K)^{1/2}$ so (same λ means) $m E_K$ (in equation) is the same for electron as for the neutron). So E_K is (much) greater as electron mass is (much) smaller than neutron mass (owtte) Note ; allow use of eV in place of E_K if eV is identified as E_K .

3	(a)	Quality of written communication: Good – Excellent (5-6 marks) The candidate provides a comprehensive, coherent and logical explanation which recognises what a stationary wave is and that the conditions for the formation of a stationary wave are present. They should know that nodes and antinodes are formed at alternate positions along XY which are equally spaced with nodes every half wavelength. They should know how the detector is used to locate the position of each node or antinode and how the wavelength is determined from the distance between two such positions. They may know that the nodes can be located more accurately than the antinodes and that their chosen two positions should be as far apart as possible. Their answer should be well-presented in terms of spelling, punctuation and grammar. Modest – Adequate (3-4 marks) The candidate provides a logical explanation which recognises what a stationary wave is and what some of the conditions for the formation of a stationary wave are. They may know that nodes and antinodes are formed at alternate positions along XY with nodes every half- wavelength. They may know how the detector is used to locate the position of each node or antinode and how the wavelength is determined from the distance between two such positions. They may know that the nodes can be located more accurately than the antinodes and that their chosen two positions should be as far apart as possible. Their answer should be well-presented in terms of spelling, punctuation and grammar. Poor to Limited (1-2 marks) The candidate may recognise that the reflector reflects radio waves which then form a stationary wave pattern with the	6 For top band , explanation = at least b and e description = at least f, g,h Explanation of stationary wave formation :- - radio waves from the transmitter are reflected back towards the transmitter✓ - reflected and incident waves pass through each other ✓ - both waves have same frequency (and speed) and amplitude✓ - superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓ (equally spaced) nodes and antinodes formed along XY✓ Description of measurement of wavelength :- - Detector signal is zero (or least) along XY at nodes ✓ - distance between adjacent nodes is $\frac{1}{2} \lambda$ ✓ - move detector along XY to measure distance between adjacent nodes and double to give the wavelength ✓ - measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓
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		incident waves. They may be unaware what the conditions for the formation of a stationary wave are and their understanding of nodes and antinodes may be poor. They may have some awareness that the stationary wave causes the detector signal to vary with position along XY and that the wavelength can be determined from this variation although they might not be able to link the wavelength to the changes of detector position correctly. Their answer may lack coherence and may contain a significant number of errors in terms of spelling and punctuation. The explanations expected in a good answer should include most of the following physics ideas Explanation of stationary wave formation :- - radio waves from the transmitter are reflected back towards the transmitter✓ - reflected and incident waves pass through each other ✓ - both waves have same frequency (and speed) and amplitude✓ - superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓ - equally spaced nodes and antinodes formed along XY✓ Description of measurement of wavelength :- - Detector signal is zero (or least) along XY at nodes ✓ - distance between adjacent nodes is $\frac{1}{2} \lambda$ ✓ - move detector along XY to measure distance between adjacent nodes and double to give the wavelength ✓ - measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓	For middle band , explanation = at least any two of a-e description = at least any two of f-i For lowest band , Any 2 points ,must be 1 of each for 2 marks Explanation of stationary wave formation :- - radio waves from the transmitter are reflected back towards the transmitter✓ - reflected and incident waves pass through each other ✓ - both waves have same frequency (and speed) and amplitude✓ - superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓ (equally spaced) nodes and antinodes formed along XY✓ Description of measurement of wavelength :- - Detector signal is zero (or least) along XY at nodes ✓ - distance between adjacent nodes is $\frac{1}{2} \lambda$ ✓ - move detector along XY to measure
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					distance between adjacent nodes and double to give the wavelength ✓ i. measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓
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3	(b)		Speed of radio waves (obtained by Hertz) is the same as the speed of light ✓ Speed of electromagnetic waves (calculated or predicted by Maxwell) is the same as the speed of light (or of radio waves) so radio waves are electromagnetic waves ✓	2	
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4	(a)		(Using $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$ gives) $2 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ or $\sqrt{1 - \frac{v^2}{c^2}} = 0.5$ ✓ (Rearranging gives) $v (= \sqrt{1 - 0.5^2} c) = 0.866 c$ or $2.6 \times 10^8 \text{ m s}^{-1}$ ✓	2	Accept either answer.
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4	(b)	curve starts at $v=0$, $m = m_0$ and rises smoothly ✓ curve passes through $2m_0$ at $v = 0.87 c$ ($\pm 0.03c$ or in 2nd half of x-scale div containing $0.87c$) ✓ curve is asymptotic at $v = c$ (and does not cross or touch $v = c$ or curve back) ✓	3	2nd mark ; ecf from 4a if plotted correctly 3rd mark ; There must be visible white space between the curve and the $v = c$ line; also, the curve must reach $7m_0$ at least.
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4	(c)	Energy = mc^2 so (as $v \rightarrow c$) energy of particle increases as mass increases ✓ mass $\rightarrow$ infinity as $v \rightarrow c$ so energy $\rightarrow$ infinity which is (physically) <u>impossible</u> ✓ [OR for one mark only force = ma so force increases as mass increases Mass $\rightarrow$ infinity as $v \rightarrow c$ so force $\rightarrow$ infinity which is (physically) <u>impossible</u>✓]	2	Alternative scheme for 1 mark only ; mass infinite at $v = c$ which is (physically) <u>impossible</u> ✓
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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
TOTAL	



General Certificate of Education
Advanced Level Examination
June 2012

Physics A

PHYA5/2D

Unit 5D Turning Points in Physics Section B

Monday 18 June 2012 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a ruler
- a Data and Formulae Booklet (enclosed).

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 50 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this section is 35.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



J U N 1 2 P H Y A 5 2 D 0 1

WMP/Jun12/PHYA5/2D

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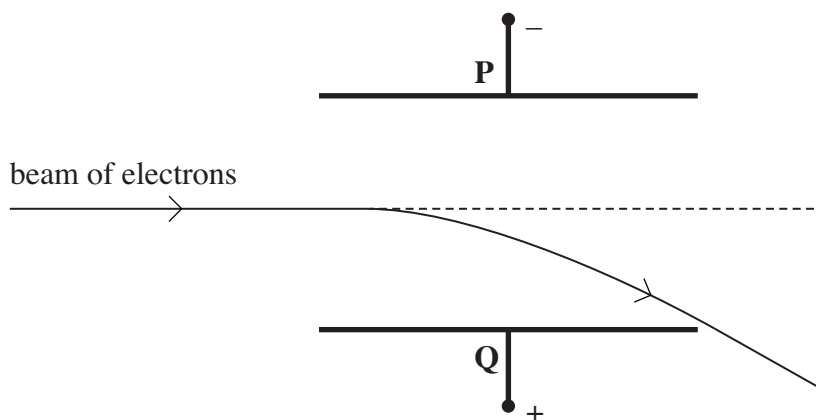
PHYA5/2D

Section B

The maximum mark for this section is 35 marks. You are advised to spend approximately 50 minutes on this section.

- 1** A narrow beam of electrons is directed into the region between two parallel plates, **P** and **Q**. When a constant potential difference is applied between the two plates, the beam curves downwards towards plate **Q** as shown in **Figure 1**.

Figure 1



- 1 (a)** Explain why the beam curves downwards at an increasing angle to its initial direction.

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(3 marks)

- 1 (b)** A uniform magnetic field is then applied at right angles to both the beam and the electric field between the plates **P** and **Q**. As a result, the downward deflection of the beam is increased.

- 1 (b) (i)** The arrangement is to be used to determine the speed of the electrons in the beam. Describe what adjustments to the flux density B of the magnetic field should be made to reduce the deflection of the beam to zero.

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(1 mark)



- 1 (b) (ii) Explain why the electrons pass undeflected through the fields when their speed v is given by

$$v = \frac{V}{Bd}$$

where V is the potential difference between plates **P** and **Q** and d is the perpendicular distance between the plates.

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(2 marks)

- 1 (c) The beam of electrons was produced by thermionic emission from a heated filament. When the potential difference between the anode and the filament was 4200 V, the speed of the electrons in the beam was $3.9 \times 10^7 \text{ m s}^{-1}$.

Use this information to determine the specific charge of the electron.

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answer = ... C kg^{-1}
(3 marks)



- 2 (a)** Describe, in terms of electric and magnetic fields, a plane polarised electromagnetic wave travelling in a vacuum. You may wish to draw a labelled diagram.

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(3 marks)

- 2 (b)** In his theory of electromagnetic waves, Maxwell predicted that the speed of all electromagnetic waves travelling through free space is given by

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

where μ_0 is the permeability of free space and ϵ_0 is the permittivity of free space.

Explain why this prediction led to the conclusion that light waves are electromagnetic waves.

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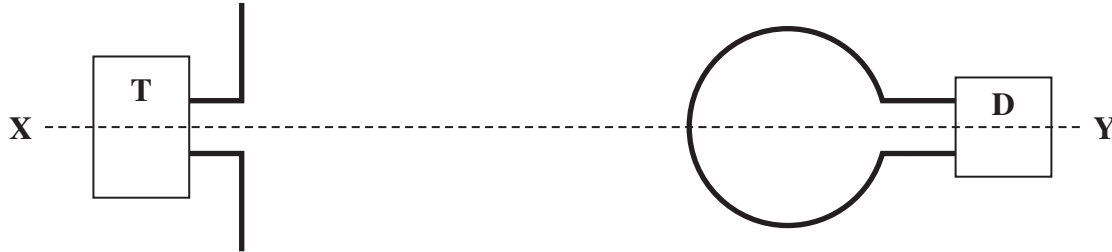
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(2 marks)



- 2 (c)** Hertz discovered how to produce and detect radio waves. **Figure 2** shows a transmitter of radio waves, **T**, and a detector **D**. The detector loop and the transmitter aerial are in the same vertical plane.

Figure 2



- 2 (c) (i)** Explain why an alternating emf is induced in the loop when it is in this position.

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(3 marks)

- 2 (c) (ii)** Explain why an alternating emf **cannot** be detected if the detector loop is turned through 90° about the axis **XY**.

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(1 mark)



The quality of your written communication will be assessed in your answer.

This image shows a single page of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

3 (b) An electron is travelling at a speed of $0.890c$ where c is the speed of light in free space.

3 (b) (i) Show that the electron has a de Broglie wavelength of $1.24 \times 10^{-12} \text{ m}$.

(2 marks)

3 (b) (ii) Calculate the energy of a photon of wavelength $1.24 \times 10^{-12} \text{ m}$.

answer = ... J
(1 mark)

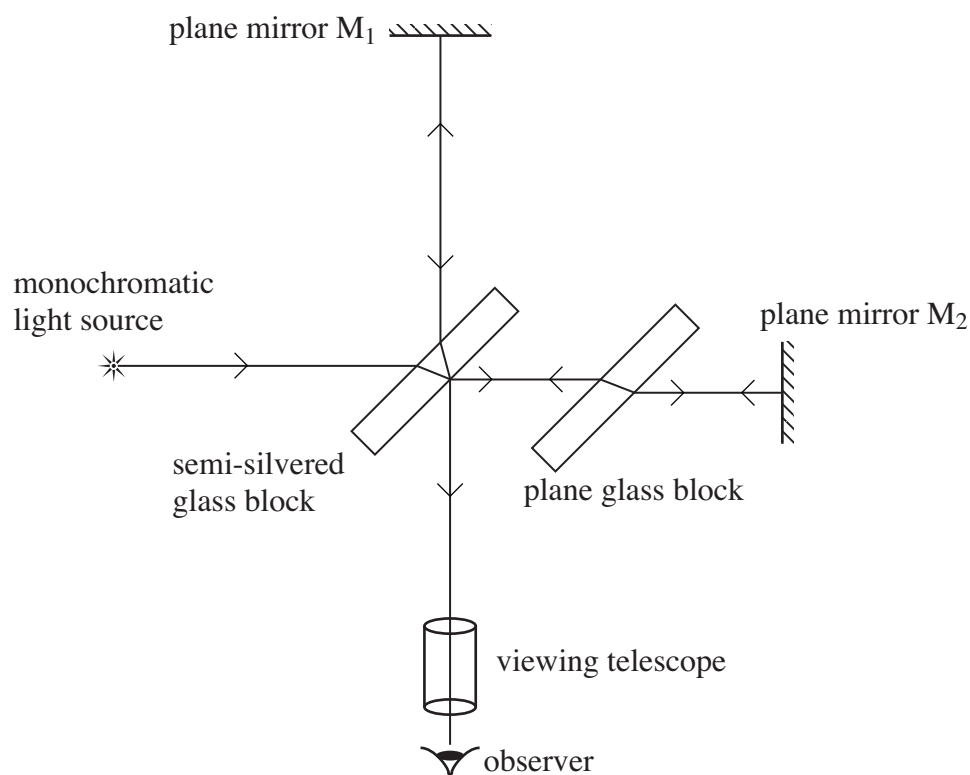
3 (b) (iii) Calculate the kinetic energy of an electron with a de Broglie wavelength of $1.24 \times 10^{-12} \text{ m}$.
Give your answer to an appropriate number of significant figures.

answer = ... J
(2 marks)



- 4 **Figure 3** represents the Michelson-Morley interferometer. Interference fringes are seen by an observer looking through the viewing telescope.

Figure 3



- 4 (a) Explain why the interference fringes shift their position if the distance from either of the two mirrors to the semi-silvered block is changed.

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(2 marks)



4 (b) Michelson and Morley predicted that the interference fringes would shift when the apparatus was rotated through 90° . When they tested their prediction, no such fringe shift was observed.

4 (b) (i) Why was it predicted that a shift of the fringes would be observed?

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(3 marks)

4 (b) (ii) What conclusion was drawn from the observation that the fringes did not shift?

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(1 mark)

6

END OF QUESTIONS



There are no questions printed on this page

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General Certificate of Education (A-level)
June 2012

Physics A

PHYA5/2D

(Specification 2450)

Unit 5/2D: Turning Points in Physics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from: aqa.org.uk

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Instructions to Examiners

- 1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.
- 2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	<i>see specific mark scheme</i>	5-6
Modest - Adequate	<i>see specific mark scheme</i>	3-4
Poor - Limited	<i>see specific mark scheme</i>	1-2
The description and/or explanation expected in a good answer should include a coherent account of the following points: <i>see specific mark scheme</i>		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

- 3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.
- 4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.
- 5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.
- 6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.
- 7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

GCE Physics, Specification A, PHYA5/1, Nuclear and Thermal Physics

1	a		$\Delta T = \left(\frac{\Delta Q}{mc}\right) = \frac{8.5 \times 10^3}{4200 \times 0.12} \checkmark$ 17 K $\checkmark$	2
1	b		$\left(\frac{\Delta T}{\Delta t} = \frac{\frac{\Delta Q}{mc}}{\Delta t}\right) = \frac{100 - 26}{\Delta t} = \frac{8.5 \times 10^3}{0.41 \times 4200} \checkmark$ $t = 15 \text{ s} \checkmark$	2
2	a		$({}^{206}_{76}\text{X} \rightarrow {}^{206}_{82}\text{Pb} + \beta \times {}^0_{-1}\beta + \beta \times \bar{\nu}_e)$ $\beta = 6 \checkmark$	1
2	b	i	the energy required to split up the nucleus $\checkmark$ into its individual neutrons and protons/nucleons $\checkmark$ (or the energy released to form/hold the nucleus $\checkmark$ from its individual neutrons and protons/nucleons $\checkmark$)	2
2	b	ii	$7.88 \times 206 = 1620 \text{ MeV} \checkmark$ (allow 1600-1640 MeV)	1
2	c	i	U, a graph starting at 3×10^{22} showing exponential fall passing through 0.75×10^{22} near 9×10^9 years $\checkmark$ Pb, inverted graph of the above so that the graphs cross at 1.5×10^{22} near 4.5×10^9 years $\checkmark$	2
2	c	ii	(u represents the number of uranium atoms then) $\frac{u}{3 \times 10^{22} - u} = 2$ $u = 6 \times 10^{22} - 2u \checkmark$ $u = 2 \times 10^{22} \text{ atoms}$	1
2	c	iii	(use of $N = N_0 e^{-\lambda t}$) $2 \times 10^{22} = 3 \times 10^{22} \times e^{-\lambda t} \checkmark$ $t = \ln 1.5 / \lambda$ (use of $\lambda = \ln 2 / t_{1/2}$) $\lambda = \ln 2 / 4.5 \times 10^9 = 1.54 \times 10^{-10} \checkmark$ $t = 2.6 \times 10^9 \text{ years} \checkmark$ (or $2.7 \times 10^9 \text{ years}$)	3
3	a		any 2 from: the sun, cosmic rays, radon (in atmosphere), nuclear fallout (from previous weapon testing), any radioactive leak (may be given by name of incident) nuclear waste, carbon-14 $\checkmark$	1

3	b	i	(ratio of area of detector to surface area of sphere) ratio = $\frac{0.0015}{4\pi(0.18)^2}$ ✓ 0.0037 ✓ (0.00368)	2
3	b	ii	activity = $0.62/(0.00368 \times 1/400)$ give first mark if either factor is used. 67000 ✓ Bq accept s^{-1} or decay/photons/disintegrations s^{-1} but not counts s^{-1} ✓ (67400 Bq)	3
3	c		(use of the inverse square law) $\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$ or calculating $k = 0.020$ from $I = k/x^2$ ✓ $I_2 = 0.62 \times \left(\frac{0.18}{0.28}\right)^2$ ✓ 0.26 counts s^{-1} ✓ (allow 0.24-0.26)	3
4	a	i	$n = PV/RT = 3.2 \times 10^5 \times 1.9 \times 10^{-3}/8.31 \times 285$ $n = 0.26$ mol ✓ (0.257 mol)	1
4	a	ii	$P_2 = \frac{T_2}{T_1} \times P_1 = \frac{295}{285} \times 3.20 \times 10^5$ ✓ 3.31×10^5 Pa ✓ (allow 3.30 - 3.35×10^5 Pa) 3 sig figs ✓ sig fig mark stands alone even with incorrect answer	3
4	b		similar - (rapid) random motion - range of speeds different - mean kinetic energy - root mean square speed - frequency of collisions	2
5	a		graph starting (steeply) near/at the origin and decreasing in gradient ✓	1
5	b	i	(use of density = mass/volume) $\frac{197 \times 1.67 \times 10^{-27}}{\frac{4}{3}\pi(6.87 \times 10^{-15})^3}$ ✓✓ mark for top line and mark for bottom line (allow use of 1.66×10^{-27}) Lose mass line mark if reference is made to mass of electrons $= 2.4(2) \times 10^{17}$ kg m^{-3}	2

5	b	ii	$R_{A1} = R_{Au} \left(\frac{A_{A1}}{A_{Au}} \right)^{\frac{1}{3}} = 6.87 \times 10^{-15} \left(\frac{27}{197} \right)^{\frac{1}{3}} \checkmark$ $= 3.54 \times 10^{-15} \text{ m } \checkmark$ or $r_0 = \frac{R}{A^{\frac{1}{3}}} = \frac{6.87 \times 10^{-15}}{197^{\frac{1}{3}}} = 1.18 \times 10^{-15} \text{ m } \checkmark$ $R = 1.18 \times 10^{-15} \times 27^{\frac{1}{3}} = 3.54 \times 10^{-15} \text{ m } \checkmark$ or $\text{volume} = \text{mass/density} = \frac{27 \times 1.67 \times 10^{-27}}{2.42 \times 10^{17}} = \frac{4}{3} \pi \times R^3 \checkmark$ $= 3.54 \times 10^{-15} \text{ m } \checkmark$	2
5	c		The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. <i>The candidate makes 5 to 6 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method</i> Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. <i>The candidate makes 3 to 4 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method</i> Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. <i>The candidate makes 1 to 2 points concerning the principles of the method, the limitations to the accuracy and the advantages and disadvantages of a particular method</i>	max 6

			The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences. principles • α scattering involves coulomb or electrostatic repulsion • electron diffraction treats the electron as a wave having a de Broglie wavelength • some reference to an equation, for example $\lambda = h/mv$; $eV = mv^2/2$; $Qq/4\pi\epsilon_0 r = E_\alpha$; $\sin\theta = 0.61\lambda/R$ • reference to first minimum for electron diffraction accuracy • α's only measure the least distance of approach, not the radius • α's have a finite size which must be taken into account • electrons need to have high speed/kinetic energy • to have a small wavelength or wavelength comparable to nuclear diameter, the wavelength determines the resolution • the wavelength needs to be of the same order as the nuclear diameter for significant diffraction • requirement to have a small collision region in order to measure the scattering angle accurately • importance in obtaining monoenergetic beams • cannot detect alpha particles with exactly 180° scattering • need for a thin sample to prevent multiple scattering advantages and disadvantages • α-particle measurements are disturbed by the nuclear recoil • Mark for α-particle measurements are disturbed by the SNF when coming close to the nucleus or electrons are not subject to the strong nuclear force. • A second mark can be given for reference to SNF if they add electrons are leptons or alpha particles are hadrons. • α's are scattered only by the protons and not all the nucleons that make up the nucleus • visibility – the first minimum of the electron diffraction is often difficult to determine as it superposes on other scattering events	
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GCE Physics, Specification A, PHYA5/2D, Turning Points in Physics

1	a		force due to electric field acts (vertically) downwards on electrons ✓ <u>vertical</u> (component) of velocity of each electron increases ✓ horizontal (component of) velocity unchanged (so angle to initial direction increases ✓	3
1	b	i	magnetic flux density should be <u>reversed</u> and adjusted in strength (gradually until the beam is undeflected) ✓	1
1	b	ii	<u>magnetic</u> (field) force = Bev and <u>electric</u> (field) force = eV/d ✓ (Accept Q or q as symbol for e (charge of electron) $Bev = eV/d$ (for no deflection) gives $v = V/Bd$ ✓	2
1	c		(gain of) kinetic energy of electron = work done by anode pd or $\frac{1}{2} m v^2 = e V_{(A)}$ ✓ $\frac{e}{m} \left(= \frac{v^2}{2 V_{(A)}} \right) = \frac{(3.9 \times 10^7)^2}{2 \times 4200}$ ✓ $= 1.8 \times 10^{11} \text{ C kg}^{-1}$ ✓	3
2	a		(vibrations of) the electric wave and magnetic wave; perpendicular to each other ✓ perpendicular to direction of propagation ✓ in phase with each other ✓	3
2	b		μ_0 and ϵ_0 determined experimentally (or μ_0 and ϵ_0 values were known) ✓ (substitution of values of μ_0 and ϵ_0 into) predicted equation gives $3(.0) \times 10^8 \text{ m s}^{-1}$ (or the speed of light) ✓ which is the speed of light (or $3(.0) \times 10^8 \text{ m s}^{-1}$) ✓	max 2
2	c	i	magnetic wave vibrations perpendicular to (plane of) loop ✓ (magnetic wave) causes alternating (or changing) magnetic flux (linkage or cutting) through the loop ✓ alternating magnetic flux (or field) induces an alternating (or changing) emf (or pd) in the loop ✓ [or equivalent E-field statements E-wave (or field) vibrations parallel to loop ✓ E-wave (or field) induces emf (or pd) in wire of loop ✓ E-wave (or field) alternates so induced emf is alternating ✓]	3

2	c	ii	no magnetic flux (linkage or cutting) through the loop (as loop is now parallel to magnetic wave vibrations) so no induced emf (or pd) ✓ (or electric field perpendicular to loop so no induced emf (or pd) ✓)	1
3	a		The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. <i>The candidate provides a comprehensive and coherent answer that includes a stated property of light such as interference or diffraction that can only be explained in terms of the wave nature of light and a <u>stated property</u> such as photoelectricity that can only be explained in terms of the particle nature of light. In each case, a relevant specific <u>observational feature</u> should be referred to and should be accompanied by a <u>coherent explanation</u> of the observation. Both explanations should be relevant and <u>logical</u>.</i> <i>For full marks, the candidate may show some appreciation as to why the specific feature of either the named wave property cannot be explained using the particle nature of light or the named particle property cannot be explained using the wave nature of light.</i> Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. <i>The candidate provides a logical and coherent explanation that includes a stated property of light such as interference or diffraction that can only be explained in terms of the wave nature of light and a stated property such as photoelectricity that can only be explained in terms of the particle nature of light.</i> <i>For 4 marks, the candidate should be able to refer to a relevant specific observational feature of each property, at least one of which should be followed by an adequate explanation of the observation. Candidates who fail to refer to a relevant specific observational feature for one of the properties may be able to score 3 marks by providing an <u>adequate</u> explanation of the observational feature referred to.</i>	max 6

			Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. <i>The candidate provides some relevant information relating to two relevant stated properties for 1 mark. Their answer may lack coherence and may well introduce irrelevant or incorrect physics ideas in their explanation.</i> Points that can be used to support the explanation: Wave-like nature property - property is either interference or diffraction - observational feature is either the bright and dark fringes of a double slit interference pattern or of the single slit diffraction pattern (or the spectra of a diffraction grating) - explanation of bright or dark fringes (or explanation of diffraction grating spectra) in terms of path or phase difference - particle/corpuscular theory predicts two bright fringes for double slits or a single bright fringe for single slit or no diffraction for a diffraction grating Particle-like nature - property is photoelectricity - observational feature is the existence of the threshold frequency for the incident light or instant emission of electrons from the metal surface - explanation of above using the photon theory including reference to photon energy hf, the work function of the metal and '1 photon being absorbed by 1 electron' - wave theory predicts emission at all light frequencies or delayed emission for (very) low intensity	
3	b	i	$m (= m_0 (1 - v^2 / c^2)^{-0.5} = 9.11 \times 10^{-31} (1 - 0.890^2)^{-0.5})$ $ (= 1.998 \times 10^{-30} \text{ kg}) = 2.0(00) \times 10^{-30} \text{ kg } \checkmark$ $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{2.0(0) \times 10^{-30} \times 0.89(0) \times 3.0(0) \times 10^8} \checkmark$ $ (= 1.2(4) \times 10^{-12} \text{ m})$	2
3	b	ii	$E_{ph} = (hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^8}{1.24 \times 10^{-12}}) = 1.6(0) \times 10^{-13} \text{ J } \checkmark$	1
3	b	iii	$E_K = (m - m_0) c^2$ $ = (1.998 \times 10^{-30} - 9.11 \times 10^{-31}) \times (3.0 \times 10^8)^2$ $ = 9.78 \times 10^{-14} \text{ J } \checkmark \text{ 3 sf only } \checkmark$	2

4	a		bright (or dark) fringe is seen where the two beams are in phase (or out of phase by 180°) ✓ changing the distance to either mirror changes the path (or phase) difference (between the two beams) so fringes shift ✓	2
4	b	i	speed of light was thought to depend on the speed of the light source (or the speed of the observer) ✓ (or on the motion of the Earth (through the aether)) distance travelled by each beam unchanged (by rotation) ✓ time difference between the two beams would change on rotation ✓ phase difference would therefore change (so fringes would shift) ✓	max 3
4	b	ii	speed of light is independent of the speed (or motion) of the light source (or the observer) ✓ (or 'aether' hypothesis incorrect (owtte)) or absolute motion does not exist)	1

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Centre Number						Candidate Number				
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Other Names										
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3	
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TOTAL	



General Certificate of Education
Advanced Level Examination
June 2011

Physics A

PHYA5/2D

Unit 5D Turning Points in Physics Section B

Monday 27 June 2011 9.00 am to 10.45 am

For this paper you must have:

- a calculator
- a ruler
- a Data and Formulae Booklet.

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 50 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this section is 35.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



J U N 1 1 P H Y A 5 2 D 0 1

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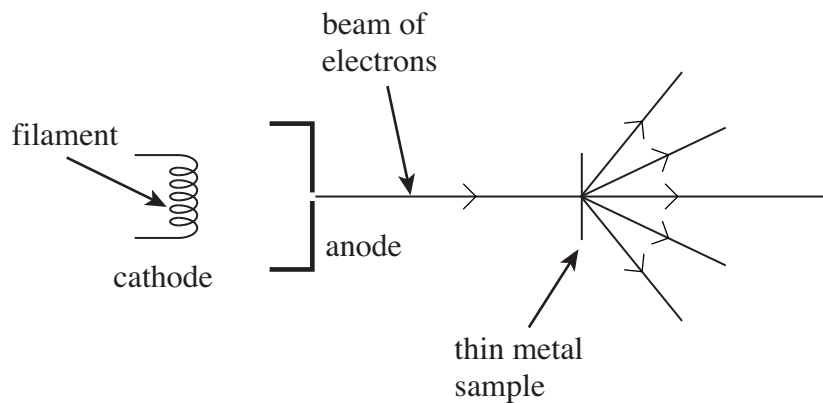
PHYA5/2D

Section B

The maximum mark for this section is 35 marks. You are advised to spend approximately 50 minutes on this section.

- 1** In **Figure 1**, a beam of monoenergetic electrons is produced by thermionic emission from a wire filament in an evacuated tube. The beam is directed at a thin metal sample at normal incidence and it emerges from the sample in certain directions only, including its initial direction.

Figure 1



- 1 (a) (i)** Name the physical process occurring at the thin metal sample in **Figure 1** which shows the electrons behaving as waves.

.....

.....

(1 mark)

- 1 (a) (ii)** Explain why the electrons need to be monoenergetic in order for them to emerge in certain directions only.

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(2 marks)



1 (b) A transmission electron microscope (TEM) operating at an anode potential of 25 kV is used to observe an image of a thin sample.

1 (b) (i) Calculate the momentum of the electrons emerging from the anode, stating an appropriate unit.

answer = ...
(4 marks)

1 (b) (ii) Describe and explain how the resolution of the image would change if the anode potential were increased.

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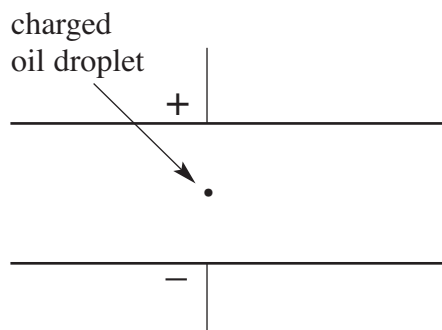
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(3 marks)



- 2 In an experiment to measure the charge of the electron, a charged oil droplet of unknown mass was observed between two horizontal parallel metal plates, as shown in **Figure 2**.

Figure 2



- 2 (a) The droplet was observed falling vertically at its terminal speed when the pd between the plates was zero.
- 2 (a) (i) By considering the forces acting on the droplet as it falls at its terminal velocity, v , show that the radius, r , of the droplet is given by

$$r = \left(\frac{9\eta v}{2\rho g} \right)^{\frac{1}{2}}$$

where η is the viscosity of air and ρ is the density of the oil droplet.

(2 marks)

- 2 (a) (ii) Explain how the mass of the oil droplet can be determined from its radius, r .

.....

.....

.....

(1 mark)



- 2 (b) (i)** The two horizontal parallel metal plates were 5.0 mm apart. The mass of the droplet was 6.8×10^{-15} kg.
The droplet was held stationary when the plate pd was 690 V.

Calculate the charge of the oil droplet, expressing your answer to an appropriate number of significant figures.

answer C
(3 marks)

- 2 (b) (ii)** Millikan made the first accurate measurements of the charge carried by charged oil droplets. Outline what Millikan concluded from these measurements.

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(2 marks)

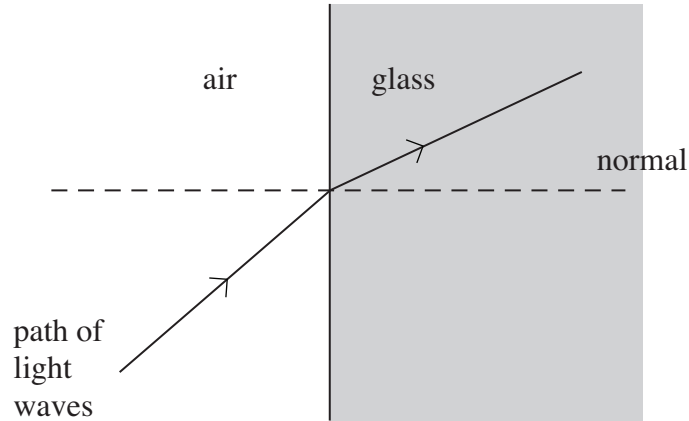
Turn over for the next question

Turn over ►



- 3 (a)** Newton suggested a theory that light is composed of corpuscles. He used his theory to explain the refraction of a light ray travelling from air to glass, as shown in **Figure 3**. Huygens explained the refraction of light using his own theory that light consists of waves.

Figure 3



- 3 (a) (i)** State **one** reason why Huygens' theory of light was rejected for many years after it was first proposed, in favour of Newton's corpuscular theory of light.

.....

.....

(1 mark)

- 3 (a) (ii)** Explain why the eventual measurement of the speed of light in water led to the definite conclusion that light consists of waves and not corpuscles.

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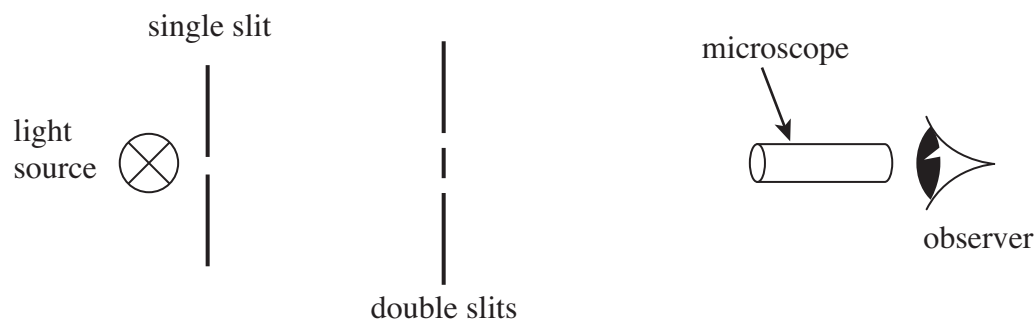
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(2 marks)



3 (b) Young demonstrated that a pattern of alternate bright and dark fringes was observed when light from a narrow single slit passed through double slits, as shown in **Figure 4**.

Figure 4



Newton's corpuscular theory predicted incorrectly that just two bright fringes would be formed in this pattern. Use Huygens' theory of light to explain why more than two bright fringes are formed in this pattern.

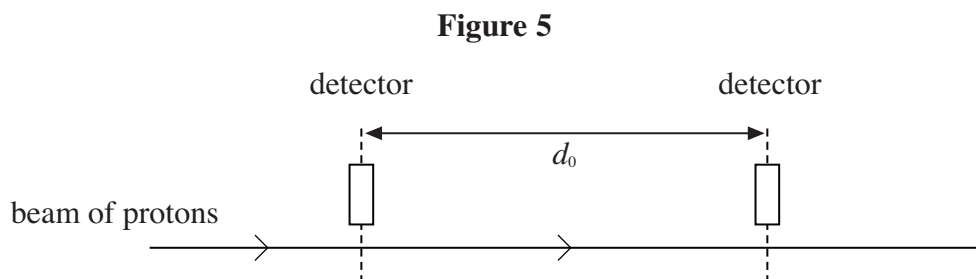
The quality of your written communication will be assessed in this question.

[illegible]

(6 marks)



- 4 In an experiment, a beam of protons moving along a straight line at a constant speed of $1.8 \times 10^8 \text{ m s}^{-1}$ took 95 ns to travel between two detectors at a fixed distance d_0 apart. As shown in **Figure 5**.



- 4 (a) (i) Calculate the distance d_0 between the two detectors in the frame of reference of the detectors.

answer = ... m
(1 mark)

- 4 (a) (ii) Calculate the distance between the two detectors in the frame of reference of the protons.

answer = ... m
(2 marks)



4 (b) A proton is moving at a speed of $1.8 \times 10^8 \text{ m s}^{-1}$

Calculate the ratio

$$\frac{\text{kinetic energy of the proton}}{\text{rest energy of the proton}}$$

answer = ...
(5 marks)

8

END OF QUESTIONS



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General Certificate of Education (A-level)
June 2011

Physics A

PHYA5/2D

(Specification 2450)

Unit 5/2D: Turning Points in Physics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Instructions to Examiners

- 1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.
- 2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	<i>see specific mark scheme</i>	5-6
Modest - Adequate	<i>see specific mark scheme</i>	3-4
Poor - Limited	<i>see specific mark scheme</i>	1-2
The description and/or explanation expected in a good answer should include a coherent account of the following points: <i>see specific mark scheme</i>		

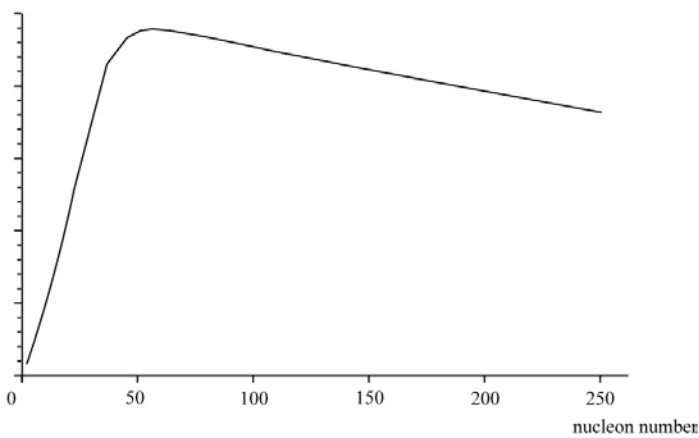
Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

- 3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.
- 4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.
- 5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.
- 6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.
- 7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

GCE Physics, Specification A, PHYA5/1, Nuclear and Thermal Physics

Question 1		
a	${}_{91}^{233}\text{Pa}$ ✓ anti (electron) neutrino ✓	2
b		2
c i	$x = 4$ ✓	1
c ii	mass defect = $[(232.98915 + 1.00867) - (90.90368 + 138.87810 + 4 \times 1.00867)] \text{ u}$ ✓ $= 0.18136 \text{ u}$ ✓ energy released $(= 0.18136 \times 931) = 169 \text{ (MeV)}$ ✓	3
Total		8

Question 2		
a	${}_{13}^{27}\text{Al} + \alpha \rightarrow {}_{15}^{30}\text{P} + {}_0^{(1)}\text{n}$ ✓	1
b	kinetic energy lost by the α particle approaching the nucleus is equal to the potential energy gain ✓ $2.18 \times 10^{-12} = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{13 \times 1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19}}{r}$ ✓ $r = 2.75 \times 10^{-15} \text{ (m)}$ ✓	3
Total		4

Question 3		
a	binding energy per nucleon  peak 8.7 (accept 8.0 – 9.2) ✓ in MeV ✓ (or peak 1.4×10^{-12} accept $1.3 - 1.5 \times 10^{-12}$ ✓ in J ✓) at nucleon number 50 – 60 ✓ accept 50 – 75 sharp rise from origin and moderate fall not below 2/3 of peak height ✓	4
b	energy is released/made available when binding energy per nucleon is increased ✓ in fission a (large) nucleus splits and in fusion (small) nuclei join ✓ the most stable nuclei are at a peak ✓ fusion occurs to the left of peak and fission to the right ✓	max 3
Total		7
Question 4		
a	(use of $\Delta Q = mc\Delta T$) $30 \times 98 = 0.100 \times c \times 14$ ✓ $c = 2100 \text{ (J kg}^{-1} \text{ K}^{-1}\text{)}$ ✓	2
b	(use of $\Delta Q = ml + mc\Delta T$) $500 \times 98 = 0.100 \times 3.3 \times 10^5$ ✓ + $0.100 \times 4200 \times \Delta T$ ✓ $(\Delta T = 38^\circ\text{C})$ $T = 38^\circ\text{C}$ ✓	3
c	the temperature would be higher ✓ as the ice/water spends more time below 25°C or heat travels in the direction from hot to cold or ice/water first gains heat then loses heat any one line ✓	2
Total		7

Question 5		
a	graph passes through given point $2.2 \times 10^{-3} \text{ m}^3$ at 0°C straight line with positive gradient ✓ (straight) line to aim or pass through -273°C at zero volume ✓	2
b	(use of $n = P V / R T$) $1.00 \times 10^5 \times 2.20 \times 10^{-3} / 8.31 \times 273$ ✓ $n = 0.0970$ (moles) ✓	2
c	(use of mean kinetic energy = $3/2 K T$) $= 3/2 \times 1.38 \times 10^{-23} \times 323$ ✓ 6.69×10^{-21} (J) ✓ 3 sfs ✓	3
d	total internal energy = $6.69 \times 10^{-21} \times 0.0970 \times 6.02 \times 10^{23} = 390$ (J) ✓	1
e	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate provides a comprehensive and coherent sequence of ideas linking the motion of molecules to the pressure they exert on a container. At least three of the first four points listed below must be given in a logical order. The description should also show awareness of how a balance is maintained between the increase in speed and shortening of the time interval between collisions with the wall to maintain a constant pressure. To be in this band, reference must be made to force being the rate of change of momentum or how, in detail, the volume compensates for the increase in temperature. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a comprehensive list of ideas linking the motion of molecules to the pressure they exert on a container. At least three of the first four points listed below are given. The candidate also knows that the mean square speed of molecules is proportional to temperature. Using this knowledge, an attempt is made to explain how the pressure is constant.	max 6

	Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate attempts the question and refers to at least two of the points listed below. Incorrect, inappropriate or no response: 0 marks No answer or answer refers to unrelated, incorrect or inappropriate physics. Statements expected in a competent answer should include some of the following marking points. molecules are in rapid random motion/many molecules are involved molecules change their momentum or accelerate on collision with the walls reference to Newton's 2nd law either $F = ma$ or $F = \text{rate of change of momentum}$ reference to Newton's 3rd law between molecule and wall relate pressure to force $P = F/A$ mean square speed of molecules is proportional to temperature as temperature increases so does change of momentum or change in velocity compensated for by longer time between collisions as the temperature increases as the volume increases the surface area increases which reduces the pressure	
	Total	14

GCE Physics, Specification A, PHYA5/2D, Turning Points in Physics

Question 1		
a	i	diffraction ✓ 1
a	ii	the electrons in the beam must have the same wavelength ✓ otherwise electrons of different wavelengths (or speeds/velocities/energies/ momenta) would diffract by different amounts (for the same order) [owtte] ✓ 2
b	i	$(eV = \frac{1}{2} m v^2 \text{ gives) either } v = \sqrt{\frac{2eV}{m}}$ or $1.6 \times 10^{-19} \times 25000 = \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2$ ✓ $v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 25000}{9.1 \times 10^{-31}}} = 9.4 \times 10^7 \text{ m s}^{-1}$ ✓ p or $mv (= 9.1 \times 10^{-31} \times 9.4 \times 10^7) = 8.5 \times 10^{-23}$ ✓ kg m s^{-1} (or Ns) ✓ alternatives for first two marks p or $mv = \sqrt{2meV}$ ✓ = $\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 25000}$ ✓ 4
b	ii	any two of the first three mark points increase of pd increases the speed (or velocity/energy/momentum) of the electrons ✓ (so) the electron wavelength would be smaller ✓ (and) the electrons would diffract less (when they pass through the lenses) ✓ and the image would show greater resolution (or be more detailed) ✓ max 3
		Total 10

Question 2		
a i	either (at terminal speed (v)) the viscous force on the droplet = its weight (or mg or the force of gravity on it) or viscous force = $6\pi\eta rv$ (where r is the radius of the droplet and η is its viscosity) and weight (= mg) = $4\pi r^3 \rho g/3$ ✓ $4\pi r^3 \rho g/3 = 6\pi\eta rv$ ✓ (which gives $r = (9\eta v/2\rho g)^{1/2}$)	2
a ii	r (can be calculated as above then) used in the formula $m = 4\pi r^3 \rho/3$ to find the droplet mass, m [owtte] ✓ alternatively; (from $6\pi\eta rv = mg$) (as all values are known use) $m = 6\pi\eta rv/g$ ✓	1
b i	electric force (or QV/d) = the droplet weight (or mg) ✓ $Q = \frac{mgd}{V} = \frac{6.8 \times 10^{-15} \times 9.8(1) \times 5.0 \times 10^{-3}}{690} = 4.8 \times 10^{-19} \text{ C}$ ✓ 2 sf answer ✓	3
b ii	any two from the charge on each droplet is a whole number $\times 1.6 \times 10^{-19} \text{ C}$ (or $\times$ charge of the electron) ✓ the least amount of charge (or the quantum of charge) is the charge of the electron ✓ the quantum of charge is $1.6 \times 10^{-19} \text{ C}$ [owtte] ✓	max 2
Total		8

Question 3		
a i	Newton's other theories were successful (or Newton was more eminent so Newton's view was accepted) ✓ alternatives, Huygens' theory was based on longitudinal waves which can not explain polarisation or Huygens' theory could not explain sharp shadows	1
a ii	either Newton predicted that light travels faster in glass than in air, Huygens' predicted the opposite ✓ or there was no evidence (for many years) that light travels slower or faster in glass than in air ✓ the speed of light in water (or glass) was (eventually) found to be less than the speed of light in air ✓ diffraction/interference observations not conclusive ✓	max 2

b	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate provides a comprehensive, coherent and logical explanation which recognises that the pattern is due to interference of light which is a wave property. They should know that at a bright fringe, the waves from the two slits are in phase and therefore reinforce each other and this can happen at positions where the path difference is zero or a whole number of wavelengths. They may not refer to the need for the waves to be coherent. Their answer should be well-presented in terms of spelling, punctuation and grammar. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a logical explanation which recognises that interference of light is a wave property. They should know either a bright fringe is where the waves from the two slits are in phase or a dark fringe is where they are out of phase by 180° and be aware there are different positions where these conditions apply. They may know the general condition for the path difference for a bright fringe or a dark fringe although they may not recognise that this condition explains why there are more than two bright fringes. Their answer should be adequately or well-presented in terms of spelling, punctuation and grammar. Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate recognises that interference of light is a wave property and that the waves from the two slits reinforce at a bright fringe or cancel at a dark fringe. They may confuse path difference and phase difference and their explanation of why there are more than two bright fringes may be vague or absent. Their answer may lack coherence and may contain a significant number of errors in terms of spelling and punctuation. Incorrect, inappropriate or no response: 0 marks No answer or answer refers to unrelated, incorrect or inappropriate physics.	max 6
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	Statements expected in a competent answer should include some of the following marking points. the pattern is due to interference of light from the two slits interference is a wave property light from the two slits is in phase at a bright fringe and therefore reinforces the path difference (from the central bright fringe to the two slits) is zero either bright fringes are formed away from the centre wherever the path difference is a whole number of wavelengths or dark fringes are formed away from the centre wherever the path difference is a whole number of wavelengths + a half wavelength the path difference for the m^{th} bright fringe from the centre is m wavelengths where m is any whole number since m is any whole number, more than two bright fringes are observed	
	Total	9

Question 4		
a i	$d_0 = (\text{speed} \times \text{time} = 1.8 \times 10^8 \times 95 \times 10^{-9}) = 17(.1) \text{ m} \checkmark$	1
a ii	$d = d_0 (1 - v^2/c^2)^{1/2}$ $= 17.1 \times (1 - (1.8 \times 10^8/3.0 \times 10^8)^2)^{1/2} \checkmark$ $= 14 \text{ m} \checkmark$ (or 13.7 m or 13.68 m) or $t = t_0 (1 - v^2/c^2)^{-1/2}$ $95 = t_0 \times (1 - (1.8 \times 10^8/3.0 \times 10^8)^2)^{-1/2}$ gives $t_0 = 76 \text{ ns} \checkmark$ $d = vt_0 = 1.8 \times 10^8 \times 76 \times 10^{-9} = 14 \text{ m} \checkmark$ (or 13.7 m or 13.68 m)	2
b	$m (= m_0 (1 - v^2/c^2)^{-1/2})$ $= 1.67(3) \times 10^{-27} \times (1 - (1.8 \times 10^8/3.0 \times 10^8)^2)^{-1/2} \checkmark$ $= 2.09 \times 10^{-27} \text{ kg} \checkmark$ kinetic energy $= (m - m_0) c^2$ or correct calculation of $E = mc^2 (= 1.88 \times 10^{-10} \text{ J})$ or correct calculation of $E_0 = m_0 c^2 (= 1.50 \times 10^{-10} \text{ J}) \checkmark$ $\frac{\text{kinetic energy}}{\text{rest energy}} = \frac{(m - m_0)c^2}{m_0 c^2} = \frac{(2.09 - 1.67) \times 10^{-27}}{1.67 \times 10^{-27}} \checkmark$ $= 0.25$ (allow 0.245 to 0.255 or $\frac{1}{4}$ or 1:4) $\checkmark$	5
	Total	8

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Other Names										
Candidate Signature										

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Question	Mark
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TOTAL	



General Certificate of Education
Advanced Level Examination
June 2010

Physics A

PHYA5/2D

Unit 5D Turning Points in Physics Section B

Tuesday 29 June 2010 1.30 pm to 3.15 pm

For this paper you must have:

- a calculator
- a ruler
- a Data and Formulae Booklet.

Time allowed

- The total time for both sections of this paper is 1 hour 45 minutes.
You are advised to spend approximately 50 minutes on this section.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

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- The maximum mark for this section is 35.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.



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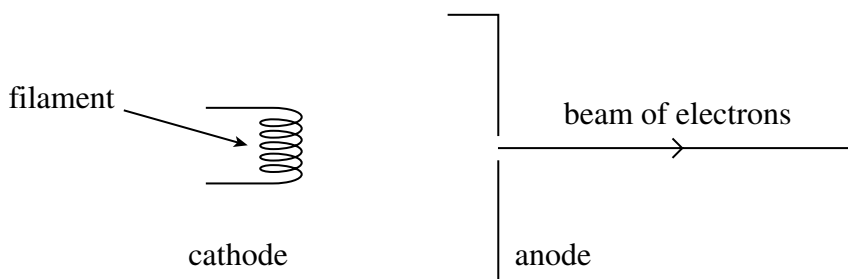
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PHYA5/2D

Section B

The maximum mark for this section is 35 marks. You are advised to spend approximately 50 minutes on this section.

- 1** A narrow beam of electrons is produced in a vacuum tube using an electron gun, part of which is shown in **Figure 1**.

Figure 1

- 1 (a) (i)** State and explain the effect on the beam of electrons of increasing the filament current.

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(2 marks)

- 1 (a) (ii)** State and explain the effect on the beam of electrons of increasing the anode potential.

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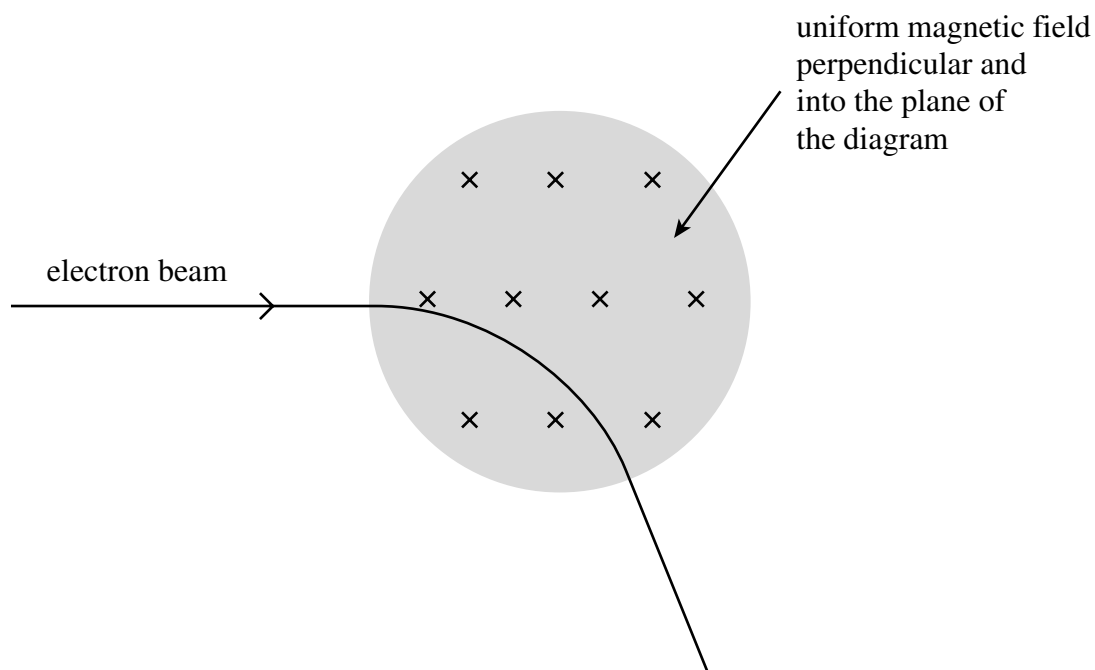
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(2 marks)



- 1 (b)** The beam of electrons is directed at right angles into a uniform magnetic field as shown in **Figure 2**.

Figure 2



- 1 (b) (i)** Explain why the electrons move in a circular path at a constant speed in the magnetic field.

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(3 marks)

Question 1 continues on the next page

Turn over ►



- 1 (b) (ii)** When the speed of the electrons in the beam is $7.4 \times 10^6 \text{ m s}^{-1}$ and the magnetic flux density is 0.60 mT, the radius of curvature of the beam is 68 mm.

Use these data to calculate the specific charge of the electron, stating an appropriate unit. Give your answer to an appropriate number of significant figures.

answer = ...
(4 marks)

- 1 (b) (iii)** Discuss the historical relevance of the value of the specific charge of the electron compared with the specific charge of the H^+ ion.

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.....
.....
.....
(2 marks)



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ANSWER IN THE SPACES PROVIDED**

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2 When light of wavelength 590 nm is directed at an uncharged surface of a certain metal X, electrons are emitted from the metal surface causing a photoelectric current.

2 (a) When the metal surface is charged positively, the photoelectric current decreases and becomes zero when the potential of the surface is +0.35 V.

2 (a) (i) Calculate the maximum kinetic energy of a photoelectron emitted from the surface when the metal surface is uncharged.

answer = ... J
(2 marks)

2 (a) (ii) Calculate the work function of the metal surface, in J.

answer = ... J
(3 marks)



2 (b) When the experiment was repeated using a different metal, Y, illuminated by light of the same wavelength, there was no photoelectric emission when the metal surface was uncharged.

2 (b) (i) Explain this observation.

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(2 marks)

2 (b) (ii) How did this observation contribute to the failure of the wave theory of light?

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(2 marks)

9

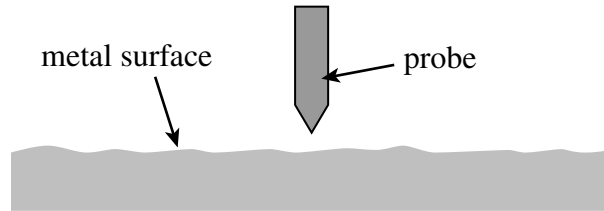
Turn over for the next question

Turn over ►



- 3** **Figure 3** shows the probe of a scanning tunnelling microscope (STM) above a metal surface.

Figure 3



- 3 (a)** Explain why electrons can cross the gap between the tip of the probe and the surface, provided

- the gap is sufficiently narrow
- a potential difference is applied between the tip and the surface.

The quality of your written communication will be assessed in this question.

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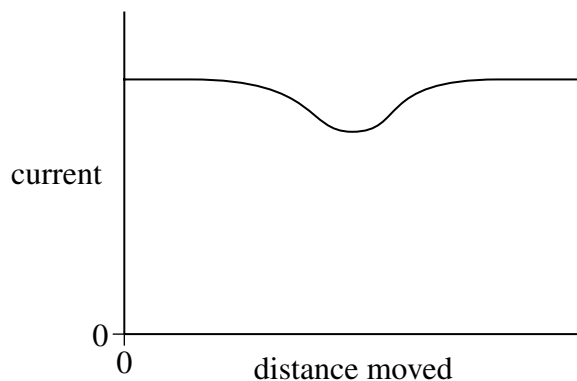
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(6 marks)



- 3 (b)** The probe is moved horizontally in a straight line across the surface. As it moves, the current due to the transfer of electrons between the surface and the probe decreases then returns to its initial value at the end of the line, as shown in **Figure 4**.

Figure 4



Explain why the current changes in this way.

.....

.....

.....

.....

(2 marks)

8

Turn over for the next question

Turn over ►



- 4 (a)** One of the two postulates of Einstein's theory of special relativity is that the speed of light in free space, c , is invariant.

Explain what is meant by this statement.

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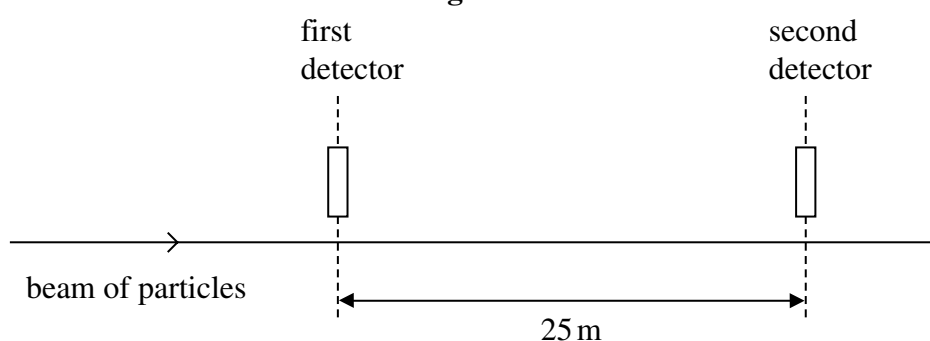
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(1 mark)

- 4 (b)** A beam of identical particles moving at a speed of $0.98c$ is directed along a straight line between two detectors 25 m apart.

Figure 5



The particles are unstable and the intensity of the beam at the second detector is a quarter of the intensity at the first detector.

Calculate the half-life of the particles in their rest frame.

answer = ... s
(4 marks)

END OF QUESTIONS



There are no questions printed on this page

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**General Certificate of Education
June 2010**

Physics A PHYA5/2D

Turning Points in Physics

Unit 5

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available to download from the AQA Website: www.aqa.org.uk

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Instructions to Examiners

- 1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.
- 2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	<i>see specific mark scheme</i>	5-6
Modest - Adequate	<i>see specific mark scheme</i>	3-4
Poor - Limited	<i>see specific mark scheme</i>	1-2
The description and/or explanation expected in a good answer should include a coherent account of the following points: <i>see specific mark scheme</i>		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

- 3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.
- 4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.
- 5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.
- 6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.
- 7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

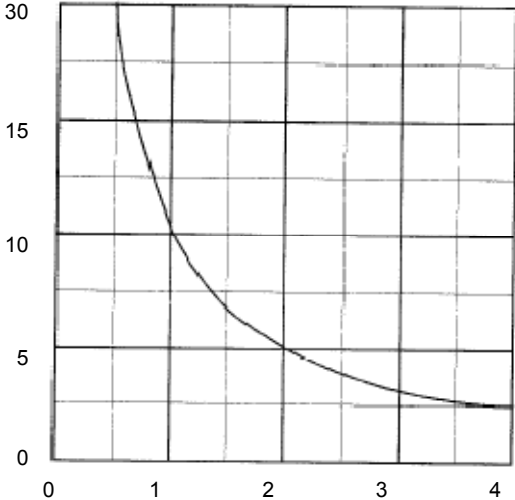
GCE Physics, Specification A, PHYA5/2D, Section A, Nuclear and Thermal Physics

Question 1		
(a)	using $Q = mc\Delta\theta$ $= 3.00 \times 440 \times (84-27) \checkmark$ $7.5 \times 10^4 \text{ (J)} \checkmark$	2
(b)	using $Q = ml$ $= 1.20 \times 2.5 \times 10^4$ $= 3.0 \times 10^4 \text{ (J)} \checkmark$	1
(c)	(heat supplied by lead changing state + heat supplied by cooling lead = heat gained by iron) $3.0 \times 10^4 + \text{heat supplied by cooling lead} = 7.5 \times 10^4 \checkmark$ heat supplied by cooling lead $= 4.5 \times 10^4 = mc\Delta\theta$ $c = 4.5 \times 10^4 / (1.2 \times (327 - 84)) \checkmark$ $c = 154 \text{ (J kg}^{-1} \text{ K}^{-1}) \checkmark$	3
(d)	any one idea $\checkmark$ no allowance has been made for heat loss to the surroundings or the specific heats may not be a constant over the range of temperatures calculated	1
	Total	7

Question 2		
(a)	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate can explain the role of the moderator and control rods in maintaining a critical condition inside the reactor. The explanation is given in a clear sequence of events and the critical condition is defined in terms of neutrons. To obtain the top mark some other detail must be included. Such as, one of the alternative scattering or absorbing possibilities or appropriate reference to critical mass or detailed description of the feedback to adjust the position of the control rods etc. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate has a clear idea of two of the following: the role of the moderator, the role of the control rods or can explain the critical condition. Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate explains that a released neutron is absorbed by uranium to cause a further fission. Alternatively the candidate may explain one of the following: the role of the moderator, the role of the control rods or can explain the critical condition. The explanation expected could include the following events that could happen to a released neutron. a neutron is slowed by the moderator taking about 50 collisions to reach thermal speeds then absorbed by uranium-235 to cause a fission event one neutron released goes on to cause a further fission is the critical condition a neutron may leave the reactor core without further interaction a neutron could be absorbed by uranium-238 a neutron could be absorbed by a control rod a neutron could be scattered by uranium-238 a neutron could be scattered by uranium-235	max 6

(b)	it is easy to stay out of range or easy to contain an α source or β/γ have greater range/are more difficult to screen ✓ most (fission fragments) are (more) radioactive/unstable ✓ and are initially most likely to be beta emitters/(which also) emit γ radiation/are neutron rich/heavy ✓ ionising radiation damages body tissue/is harmful ✓	max 3
	Total	9

Question 3		
(a)	probability of decay per unit time/given time period or fraction of atoms decaying per second or the rate of radioactive decay is proportional to the number of (unstable) nuclei and nuclear decay constant is the constant of proportionality ✓	1
(b)	use of $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ $T_{\frac{1}{2}} = \ln 2 / 3.84 \times 10^{-12} \text{ s} \checkmark (1.805 \times 10^{11} \text{ s})$ $= (1.805 \times 10^{11} / 3.15 \times 10^7) = 5730 \text{ y} \checkmark$ answer given to 3 sf ✓	3
(c)	number of nuclei = $N = 3.00 \times 10^{23} \times 1/10^{12} \checkmark$ $(= 3.00 \times 10^{11} \text{ nuclei})$ (using $\frac{\Delta N}{\Delta t} = -\lambda N$) rate of decay = $3.84 \times 10^{-12} \times 3.00 \times 10^{11} \checkmark$ $(= 1.15 \text{ Bq})$	2
(d)	$(N = N_0 e^{-\lambda t} \text{ and activity is proportional to the number of nuclei } A \propto N \text{ use of } A = A_0 e^{-\lambda t})$ $0.65 = 1.15 \times e^{-3.84 \times 10^{-12} t} \checkmark$ $t = \frac{\ln(\frac{1.15}{0.65})}{3.84 \times 10^{-12}} \text{ or } \frac{\ln(\frac{0.651}{1.15})}{-3.84 \times 10^{-12}} \checkmark$ $t = 4720 \text{ y} \checkmark$	3
(e)	the boat may have been made with the wood some time after the tree was cut down the background activity is high compared to the observed count rates the count rates are low or sample size/mass is small or there is statistical variation in the recorded results possible contamination uncertainty in the ratio of carbon-14 in carbon thousands of years ago any two ✓✓	2
	Total	11

Question 4														
(a)	pressure/10^4 Pa  curve with decreasing negative gradient that passes through the given point which does not touch the x axis ✓ <table border="1" data-bbox="410 952 873 1272"><thead><tr><th colspan="2">designated points</th></tr><tr><th>pressure/10^4 Pa</th><th>volume/10^{-3} m³</th></tr></thead><tbody><tr><td>10</td><td>1.0</td></tr><tr><td>5.0</td><td>2.0</td></tr><tr><td>4.0</td><td>2.5</td></tr><tr><td>2.5</td><td>4.0</td></tr></tbody></table> 2 of the designated points ✓✓ (one mark each)	designated points		pressure/ 10^4 Pa	volume/ 10^{-3} m ³	10	1.0	5.0	2.0	4.0	2.5	2.5	4.0	3
designated points														
pressure/ 10^4 Pa	volume/ 10^{-3} m ³													
10	1.0													
5.0	2.0													
4.0	2.5													
2.5	4.0													
(b) (i)	$N = PV/kT = 5 \times 10^4 \times 2 \times 10^{-3}/1.38 \times 10^{-23} \times 290$ ✓ [or alternative use of $PV = nRT$ $5 \times 10^4 \times 2.0 \times 10^{-3}/8.31 \times 290 = 0.0415$ moles] $= 2.50 \times 10^{22}$ molecules ✓	2												
(b) (ii)	(mean) kinetic energy of a molecule $= \frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ ✓ ($= 6.00 \times 10^{-21}$ J) (total kinetic energy = mean kinetic energy $\times N$) $= 6.00 \times 10^{-21} \times 2.50 \times 10^{22}$ ✓ $= 150$ (J) ✓	3												

(c)	all molecules/atoms are identical molecules/atoms are in random motion Newtonian mechanics apply gas contains a large number of molecules the volume of gas molecules is negligible (compared to the volume occupied by the gas) or reference to point masses no force act between molecules except during collisions or the speed/velocity is constant between collisions or motion is in a straight line between collisions collisions are elastic or kinetic energy is conserved and of negligible duration any 4 ✓✓✓✓	max 4
	Total	12

GCE Physics, Specification A, PHYA5/2D, Section B, Turning Points in Physics

Question 1		
(a) (i)	The number of electrons (per second) in the beam will increase ✓ because the filament will become hotter and will emit more electrons (per second) ✓	2
(a) (ii)	the speed (or kinetic energy) of the electrons will increase ✓ because the electrons (from the filament) are attracted towards the anode with a greater acceleration (or force) ✓ (or gain more kinetic energy in crossing a greater pd)	2
(b) (i)	(magnetic) force on each electron in the beam is perpendicular to velocity ✓ no work is done on each electron by (magnetic) force so ke (or speed) is constant ✓ magnitude of (magnetic) force is constant because speed is constant ✓ (magnetic) force is always perpendicular to velocity so is centripetal ✓	max 3
(b) (ii)	rearranging $r = \frac{mv}{Be}$ gives $\frac{e}{m} = \frac{v}{Br}$ ✓ $\frac{e}{m} = \frac{7.4 \times 10^6}{6.0 \times 10^{-4} \times 68 \times 10^{-3}} = 1.81 \times 10^{11} \text{ C kg}^{-1}$ ✓ for correct answer to 2 sf ✓	4
(b) (iii)	specific charge for the electron $\approx 2000 \times$ specific charge of H^+ ✓ (accept = and accept any value between 1800 and 2000) which was the largest known specific charge before the specific charge of the electron was determined/measured ✓ (or which could be due to a much greater charge or a much smaller mass of the electron)	2
	Total	13

Question 2		
(a) (i)	work done (due to stopping potential V) = eV ✓ $E_{K\max}$ = work done due to stopping potential $= (1.6 \times 10^{-19} \times 0.35) = 5.6 \times 10^{-20} \text{ J}$ ✓	2
(a) (ii)	(rearranging $hf = \phi + E_{K\max}$) gives $\phi = hf - E_{K\max}$ ✓ photon energy ($= hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{590 \times 10^{-9}}$) $= 3.37 \times 10^{-19} \text{ J}$ ✓ $\phi = hf - E_{K\max} = 3.37 \times 10^{-19} - 5.6 \times 10^{-20} = 2.8(1) \times 10^{-19} \text{ J}$ ✓	3
(b) (i)	photons have the same energy (as in a)) ✓ when a (conduction) electron in the metal absorbs a photon, it gains all the energy of the photon ✓ work function(of Y) is the minimum energy needed by an electron to escape ✓ work function of Y is greater than the energy gained by an electron (so electron cannot escape) ✓	max 2
(b) (ii)	wave theory predicts that incident light (of any frequency) would cause photoelectric emission (from any metal) ✓ and any one of the following points wave theory could not explain why light below a certain frequency (or below a threshold frequency) could not cause photoelectric emission ✓ or this (threshold) frequency is characteristic of the metal (or depends on the metal) ✓ or wave theory could not explain the instantaneous emission of photoelectrons ✓	2
Total		9

Question 3		
(a)	The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear. The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. High Level (Good to excellent): 5 or 6 marks The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate gives a comprehensive explanation based on the knowledge that electrons have a wave-like nature so there is a finite probability of crossing the gap. They should recognise how the transfer of electrons across the gap is affected by the gap width and why a pd is necessary and why it should be constant. Their explanation should have the key ideas linked effectively in an appropriate sequence. Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate includes the main idea that electrons can transfer or 'tunnel' across the gap because they have a 'wave-like' nature. They should show awareness that the transfer of electrons is in one direction only because a pd is applied and that the transfer is affected by the gap width. Their explanation should not include contradictory or incorrect physics ideas (eg the use of electrostatic attraction). Low Level (Poor to limited): 1 or 2 marks The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate knows that electrons have a wave-like nature and this is relevant in this context. They may show some awareness of the effect of the gap width. They may not appreciate why the wave nature of the electron is relevant here. They may well introduce irrelevant or incorrect physics ideas in their explanation. The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case. • electrons have a wave like nature • there is a finite probability that electrons can cross the gap • electrons can tunnel across the gap • pd is necessary so electrons cross in one direction only (no net transfer of electrons for zero pd) • the narrower the gap, the greater the number of electrons (per second) that cross the gap • electrons transfer from – to + • constant pd provides one less variable (to affect the current) (de Broglie) wavelength is of the order of the gap width	max 6

(b)	as the probe moves along, the gap width increases (as the current decreases) then decreases (as the current increases) ✓ the current decreases (or increases) because the tunnelling effect (or probability of crossing the gap) decreases (or increases) ✓	2
	Total	8

Question 4		
(a)	c is the same, regardless of the speed of the light source or the observer ✓	1
(b)	distance between detectors in rest frame of particles (= $25 \times (1 - 0.98^2)^{1/2}$) = 5.0 m ✓ time taken in rest frame of particles $\left(= \frac{\text{distance}}{\text{speed}} = \frac{5.0}{0.98c}\right) = 1.7 \times 10^{-8} \text{ s}$ ✓ time taken to decrease by $\frac{1}{4}$ = 2 half lives ✓ half life (= $1.7 \times 10^{-8} / 2$) = $8.5 \times 10^{-9} \text{ s}$ ✓ [alternatively] time taken in rest frame of detectors $\left(= \frac{\text{distance}}{\text{speed}} = \frac{25.0}{0.98c}\right) = 8.5 \times 10^{-8} \text{ s}$ time taken in rest frame of particles (= $8.5 \times 10^{-8} \times (1 - 0.98^2)^{1/2}$) = $1.7 \times 10^{-8} \text{ s}$]	4
	Total	5